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Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Plumbing Systems

by
Edgar S. Neely
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FOREWORD

This research was conducted for the Directorate of the Military Programs, Headquarters, U.S. Army Corps of Engineers and the Office of the Assistant Chief of Engineers under various research, development, testing, and evaluation (RDTE) and reimbursable funding documents. Work began under RDTE in 1980 and continued in reimbursable projects during 1984 through 1989. The technical monitor for the RDTE part was Dr. Larry Schindler (CEMP-EC) and for the reimbursable part was Ms. Val Corbridge (DAEN-ZCF-R).

The work was performed by the Facility Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (USACERL). The Principal Investigators were Dr. Edgar Neely and Mr. Robert Neathammer (USACERL FS). The primary contractor for much of the data development was the Department of Architectural Engineering, Pennsylvania State University. Dr. Michael O'Connor is Chief of USACERL-FS.

COL Everett R. Thomas is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

Maintenance* and repair (M&R) cost estimates are needed during planning, design, and operations/maintenance of Army facilities. During planning, life-cycle costs are needed to evaluate alternative ways of meeting requirements (e.g., lease, new construction, renovate existing facilities). During design, M&R requirements for various types of components, such as built-up or shingle roofs, are needed so that the total life-cycle cost of different designs can be minimized. Finally, once the facility has been constructed, outyear predictions of maintenance and repair costs are needed so that enough funds can be programmed to ensure that Army facilities are maintained properly and do not deteriorate due to lack of maintenance.

The Directorate of Engineering and Construction (EC), Headquarters, U.S. Army Corps of Engineers (HQUSACE),** asked the U.S. Army Construction Engineering Research Laboratory (USACERL) to coordinate the assembly of a single centralized maintenance and repair data base for use by Corps designers. This research was required because designers were not able to obtain reliable maintenance and repair data to support their life-cycle cost (LCC) analysis from installations or from the technical literature. One of the first tasks in the research effort was to determine if reliable data bases, which could be adapted for Corps use, existed in government or private industry. Comprehensive data bases of maintenance costs for government and private sector facilities did not exist. The little data available always depended on widely varying standards of maintenance used to maintain the facilities for which the data was collected and thus was unreliable for prediction purposes. Recognizing this, HQUSACE asked USACERL to develop a maintenance and repair cost data base. This data is for use by U.S. Army Corps of Engineers (USACE) designers in performing life-cycle cost analyses during the design of new facilities. Initial results were presented in several USACERL reports.[1]

Soon after this request, the Facilities Programming and Budgeting Branch of the Facilities Engineering Directorate asked USACERL to develop prediction models for outyear maintenance requirements of the Army facility inventory. The Programming Office of EC, responsible for Military Construction, Army (MCA) planning, also requested that USACERL provide methods and automated tools to help installations perform economic analyses. Part of the objective was to allow analysts to obtain future maintenance cost data.

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*Maintenance in this report means all work required to keep a facility in good operating condition; it includes all maintenance, repair, and replacement of components required over the life of a facility.

**At the time of this request, EC was part of the Office of the Chief of Engineers, which has since reorganized. In addition, EC has now become the Directorate of Military Programs.

[1] R.D. Neathammer, *Life-Cycle Cost Database Design and Sample Cost Data Development*, Interim Report P-120/ADA0997222 (U.S. Army Construction Engineering Research Laboratory [USACERL], February 1981); R.D. Neathammer, *Life-Cycle Cost Database: Vol I, Design*, and *Vol II, Sample Data Development*, Technical Report P-139/ADA126644 and ADA126645 (USACERL, January 1983), Appendices E through G.

In response to these requests, USACERL began a multiyear effort to develop a comprehensive maintenance and repair cost research program for buildings. This coordinated program is the key to all detailed estimation of future maintenance costs for Army facilities.

Research Performed and Reports Published

This is one of several interrelated reports addressing maintenance resource prediction in the facility life-cycle process. The total research effort is described in a USACERL Technical Report.[2]

The first research product was a data base containing maintenance tasks related to every building construction component. This data base provides labor, material, and equipment resource information. The frequency of task occurrence is also included. This information is published in a series of four USACERL Special Reports by engineering systems: (1) architectural, (2) heating, ventilating, and air-conditioning (HVAC), (3) plumbing, and (4) electrical. The title for the series is *Maintenance Task Data Base for Buildings*.[3] Table 1 shows an example from this data base. This data is also available in electronic form. The data base is used in a personal computer (PC) system under the Disk Operating System (DOS). This computer program allows a facility to be defined by entering the components and component quantities comprising the facility. The tasks are used to determine the resources required annually to keep the facility maintained.

The second research product was a component resource summary for the first 25 years of a facility. The tasks for the component were scheduled and combined into one set of annual resource requirements. This annual resource information is published in a series of four USACERL Special Reports titled *Building Component Maintenance and Repair Data Base*.[4] An example from this data base is shown in Table 2. The data base is also available in electronic form. This data can be used to perform special economic analyses such as one for a 20-year life using a 10 percent discount rate.

The third research product was a set of 25-year present worth factor tables for use by designers in selecting components for discount rates of 7 and 10 percent. The annual component resource values were multiplied by the appropriate present worth factor and added for the 25 years to produce one set of resource values. This information is published in a series of four USACERL Special Reports titled

[2] E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Resource Prediction in the Facility Life-Cycle Process*, Technical Report P-91/10 (USACERL, March 1991).

[3] E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/21 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Plumbing Systems*, Special Report P-91/18 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Electrical Systems*, Special Report P-91/25 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Maintenance Task Data Base for Buildings: Architectural*, Special Report P-91/23 (USACERL, May 1991).

[4] E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance and Repair Data Base for Buildings: Architectural Systems*, Special Report P-91/27 (USACERL, 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance and Repair Data Base for Buildings: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P-91/22 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance and Repair Data Base for Buildings: Plumbing Systems*, Special Report P-91/30 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Component Maintenance and Repair Data Base for Buildings: Electrical Systems*, Special Report P-91/19 (USACERL, May 1991).

Table 1

Typical Task Data Form

Task Code: 0811202

Component: FLUSH-TANK WATER CLOSET System: SANITARY Subsystem: FIXTURES

Task Desription: M/R REPLACE WASHER IN BALL COCK

Unit of Measure: COUNT Frequency of Occurence: H: 4.00 A: 5.00 L: 6.00
Once every (H,A,L) years

Persons per Team: 1 Task Duration: 0.1872 hours

Trade: PLUMBING Task Classification: 0

Labor Resources

Subtask Description	Labor Hours
1. TURN VALVE ON AND OFF	0.008000
2. REMOVE AND INSTALL COVER	0.017000
3. REMOVE AND INSTALL 2 SCREWS	0.035000
4. REMOVE/INSTALL VALVE ROD LIFTER	0.004000
5. REMOVE AND INSTALL VALVE ROD	0.004000
6. REMOVE WASHER	0.023000
7. INSTALL WASHER	0.013000
8. GRIND VALVE SEAT	0.016000
9. CHECK OPERATION	0.024000

Material Resources

Description	Quantity	Unit Cost
WASHER	1	0.1700
		0.1700

SUMMARY

Resources	UOM	Direct	Indirect	Total
Labor	Hours	0.144000	0.043200	0.187200
Material	Cost $	0.170000		0.170000
Equipment	Hours			0.187200

Table 2

Typical Component Summary

25 Year Component Listing

CACES No.: 081110-Tank-Less Water Closet | 081120 - Flush-Tank Water Closet

Labor Hours	Materials $	Equipment Hours	YR	Labor Hours	Materials $	Equipment Hours
0.0000	0.0000	0.0000	1	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	2	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	3	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	4	0.0000	0.0000	0.0000
1.5821	1.3992	1.5821	5	1.7693	1.5794	1.7693
0.0000	0.0000	0.0000	6	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	7	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	8	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	9	0.0000	0.0000	0.0000
1.6926	13.3772	1.6926	10	1.7693	1.5794	1.7693
0.0000	0.0000	0.0000	11	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	12	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	13	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	14	0.0000	0.0000	0.0000
1.5821	1.3992	1.5821	15	2.9796	18.0094	2.9796
0.0000	0.0000	0.0000	16	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	17	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	18	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	19	0.0000	0.0000	0.0000
1.6926	13.3772	1.6926	20	1.8832	1.7066	1.9032
0.0000	0.0000	0.0000	21	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	22	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	23	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	24	0.0000	0.0000	0.0000
1.5821	1.3992	1.5821	25	1.7693	1.5794	1.7693

Building Maintenance and Repair Data for Life-Cycle Cost Analyses.[5] Table 3 shows an example from this data base. The data base is also available in electronic form. The first three resource columns provide data to allow designers to calculate the life-cycle costs at any location by multiplying by the correct labor rate, equipment rate, and material geographic factor. The multiplication and addition have been performed for the Military District of Washington, DC, and results are given in the fourth column of the table. The right section of the table is information that can be entered into computer systems that perform life-cycle cost analysis.

[5] E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Architectural Systems*, Special Report P-91/17 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, and R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Heating, Ventilation, and Air-Conditioning Systems*, Special Report P 91/20 (USACERL, May 1991); E.S. Neely, R.D. Neathammer, J.R. Stirn, R.P. Winkler, *Building Maintenance and Repair Data for Life-Cycle Cost Analyses: Electrical Systems*, Special Report P-91/26 (USACERL, May 1991).

Table 3

Life-Cycle Cost Analysis

EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE CYCLE COST ANALYSIS ($ PER UNIT MEASURE)													PAGE
COMPONENT DESCRIPTION		PRESENT WORTH OF ALL 25 YEAR MAINTENANCE AND REPAIR COSTS (d = 10%)				ANNUAL MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS							
		By Resources			Washington D.C. Total	Annual Maintenance and Repair			Replacement and High Costs Tasks				
	um	labor	material	equipment		labor	material	equipment	Yr	labor	material	equipment	
PLUMBING													
SANITARY													
FIXTURES													
TANK-LESS WATER CLOSET	CT	1.89994	6.68070	1.89994	46.94	0.26563	0.93402	0.26563	35	2.02280	188.09700	1.01140	
FLUSH-TANK WATER CLOSET	CT	2.31668	4.96386	2.31668	54.05	0.32389	0.69399	0.32389	35	4.11190	79.06540	2.05595	
URINAL	CT	2.89694	10.98923	2.89694	72.38	0.40502	1.53640	0.40502	35	2.13330	167.48000	1.06665	
LAVATORY, IRON ENAMEL	CT	2.63599	17.12850	2.63599	72.99	0.36854	2.39472	0.36854	40	1.99550	138.44660	0.99775	
LAVATORY, VITREOUS CHINA	CT	2.63599	17.12850	2.63654	72.99	0.36854	2.39472	0.36854	35	1.99680	142.18840	0.99640	
LAVATORY, ENAMELED STEEL	CT	2.63654	17.12850	2.06822	73.00	0.36861	2.39472	0.36861	35	1.99680	61.79800	0.99840	
BATHTUB, CAST IRON ENAMEL	CT	4.06822	42.96166	4.06822	129.17	0.56877	6.00644	0.56877	40	13.00000	341.29880	6.50000	
BATHTUB, ENAMELED STEEL	CT	5.47173	44.30948	5.47173	160.26	0.76500	6.19488	0.76500	35	3.34100	174.12620	1.67050	
SHOWER, TERRAZO	CT	3.90504	24.15328	3.90504	106.90	0.54596	3.37685	0.54596	30	98.91700	243.69400	49.45650	
SHOWER, ENAMELED STEEL	CT	3.90504	24.15328	3.90504	106.90	0.54596	3.37685	0.54596	35	3.36700	262.88000	1.68350	
SHOWER, PLASTIC	CT	4.01848	30.66697	3.82134	115.19	0.50670	2.55230	0.50670	20	3.36700	105.98940	1.68350	

A fourth research product was a PC system that allows facilities to be modeled by entering the components that comprise the facility. Future years resource predictions are produced by applying the individual tasks and then forming resource summaries by subsystems, systems, facilities, installations, reporting installations, Major Commands (MACOMS) and Army. A summary level computer system was also developed for use by the Department of the Army (DA) and MACOMS. The summary level system applies the most basic data contained in the current facility real property inventory files: (1) current facility use, (2) floor area, and (3) construction date. Users and systems manuals will be published as USACERL ADP Reports.

Objective

The objective of this report is to describe the component summaries for plumbing systems and give examples for using these tables in performing life-cycle cost analyses during the design process.

Approach

The first activity in the research was to survey the literature for available maintenance data. No comprehensive task resource data base was located. The Navy has developed a series of manuals dealing with labor hours required to perform several basic maintenance tasks. This work has been adopted by the Department of Defense (DOD) for tri-service use. A series of Technical Bulletins (TBs) under the general title *Engineered Performance Standards* (EPS) has been published.

The next activity was to survey USACE District offices to solicit their input for a data base. A guiding committee composed of District personnel, installation representatives, and private sector consultants met and agreed upon a general data base design. More importantly, they recommended that the data base be developed using the EPS rather than historical data.

Once the data base was developed, component summaries were created by summing all tasks for a component. These summaries were then input into a program that computed present worth values for each component.

The calculation procedures described in this report were performed and summarized for standard Army life-cycle analysis of 25 years with a 7 or 10 percent worth factor. Final results are published in the USACERL Special report series *Building Maintenance and Repair Data Base for Life-Cycle Cost Analyses*.

Scope

The 25 year component resource summary tables are for DOD designers and can also be used by those in the private sector.

Mode of Technology Transfer

The tables pertinent to designer use will be issued as a supplement to Technical Manual (TM) 5-802-1, *Economic Studies for Military Construction Design—Applications*.

2 PROBLEM DEFINITION

In the facility life-cycle process, costs are incurred in construction, operation, maintenance, and disposal of a facility. Past emphasis during the planning, design, and construction phases has been on estimating initial construction costs. The impact of operating and maintaining facilities has always been a secondary consideration. In many cases, the operation and maintenance (O&M) costs are far greater than initial construction costs. Building owners are concerned with the total ownership costs of facilities rather than just the initial construction costs.

The Army has realized the importance of performing total life-cycle cost analyses for facilities at the design stage of accurately forecasting these costs for funds programming. HQUSACE asked USACERL in 1980 to develop a method of estimating future maintenance costs for buildings. In 1982, the programming branch of the former Facilities Engineering Directorate asked USACERL to develop effective models for forecasting facility maintenance resource requirements based on the actual facility.

Life-cycle cost economic studies are an integral part of facility design in the MCA program. Requirements for performing these studies are given in:

- Statutes, Code of Federal Regulations, and Executive Orders for performing analyses when energy is a key cost and for wastewater treatment plants

- USACE *Architectural and Engineering Instructions: Design Criteria*

- Army Regulation (AR) 11-28, *Economic Analysis and Program Evaluation for Resource Management* for general economic analyses

- TM 5-802-1, *Economic Studies for Military Construction Design—Applications*

The main purpose of these studies is to minimize the life-cycle costs of Army facilities.

To perform life-cycle cost analyses on facility designs, three categories of costs are needed: initial, operating, and maintenance. Initial costs are usually easy to estimate through existing cost estimating systems such as the Corps of Engineers Computer Assisted Cost Estimating System (CACES) and standard publications such as Means or Dodge. Operating costs can be estimated by using energy consumption models such as the Corps of Engineers Building Loads Analysis and System Thermodynamics (BLAST) program or the Trane Company's Trace program. However, accurate estimates of maintenance costs are not available.

There are no comprehensive data bases of maintenance costs for building components either in the private sector or State/Federal Governments. Some historical data is available from the Building Owners' and Managers' Association reports. Within the Army, the Integrated Facilities System (IFS) contains some historical data; however, it does not have a feature for retaining several types of a building component (e.g., having brick and wood exteriors or three types of floor covering). Moreover, the data in IFS has not been kept current. For example, at one installation several family housing units were shown as having wood siding when, in fact, they had been covered with aluminum siding several years earlier.

3 DATA BASE DEVELOPMENT

Introduction

Historical data within the Army and other agencies was reviewed to determine the availability of accurate resource data. The best source of labor resource data was the Engineered Performance Standards[6] adopted by DOD for use by all DOD agencies. The advisory committee decided to develop a maintenance task data base using the EPS as the basis for the labor resources.

A typical building was subdivided into systems, sub-systems, and components. All maintenance, repair and replacement tasks were listed for each component. The resources required to perform each task were identified and the significance of the task resources discussed. Component summary tables listing resources by component age were developed by combining all tasks that were scheduled to be performed during each year. A summary of labor, material, and equipment requirements was given by component age. Life-cycle costs analysis tables were created by applying discount factors to the resource given in the component summary tables. The resulting tables can be used to perform life-cycle cost analysis.

Historical Data Review

Extensive research was performed during a 3-year period of reviewing the available historical data at several installations. This research revealed that a large portion of the component replacement tasks was not performed when replacement was required, due to lack of available funding, but was completed several years later. Most replacements performed by contract were not entered into the corporate data base. Most installations maintained few historical records because there was no Army regulation requiring such records to be kept. When component replacement dates were available, the comparable component installation or previous replacement dates were unknown, thus, accurate frequencies could not be established.

The task description fields given for the tasks performed were often blank or the descriptions given were very vague. Often several tasks were reported on one entry. Most entries gave a dollar cost but provided very little information about labor hours, materials, and equipment hours. Discussions with service personnel revealed that the data recorded on the forms may not actually relate to the resources required to perform the work.

In conclusion, all maintenance personnel interviewed stated clearly and emphatically that the current historical data cannot be used to develop accurate resource predictions. This data is erroneous, incomplete, and inaccurate.

Engineered Performance Standards (EPS)

In 1955 the new use of maintenance management for public works and public utilities required that a greater portion of maintenance work be planned and estimated. The general absence, however, of adequate and reliable maintenance estimating data severely handicapped any increase in the number of

[6] Army Technical Bulletin 420-1 through 420-51.

estimates, and, more seriously, the production of accurate estimates. About this time, the Department of Defense directed that standards for work should be developed to the maximum feasible extent and applied throughout the military establishment. As a result of that directive, EPS were developed.

The Navy undertook a large research program to perform time and motion studies of maintenance personnel as they performed their maintenance tasks. After several manyears of effort, the Navy published the results under the title "EPS." Both Army and Air Force maintenance personnel reviewed this set of manuals and adopted it for official use. Today, the EPS are used by all DOD agencies and are published as one set of reports carrying three different publication numbers for the Army, Navy, and Air Force.

Committee Reviews

At the beginning of this research project HQUSACE and USACERL formed an advisory committee composed of representatives from all offices involved in performing life-cycle cost analysis. The basic objective of the advisory committee was to involve as many appropriate and knowledgeable people as possible in deciding how to solve the M&R data base problem. The advisory committee reviewed the historical information research results and the EPS research program and reports. After lengthy discussion of all possible alternatives, the advisory committee decided to develop a maintenance task data base using the EPS as the basis for the labor resources. The advisory committee was active for the first two years of the project.

A second maintenance steering committee was formed that was composed of one representative from each HQDA office involved in maintenance resource programming and planning, six major commands, and 10 installations. This maintenance steering committee had the same basic objective as the first advisory committee. In addition, the steering committee wanted to use the data developed to predict actual maintenance resource requirements at installations.

Building Subdivision

The UNIFORMAT method of dividing a building into systems, subsystems, and components was adopted because it is used by all Federal construction agencies and many private organizations. Systems requiring little maintenance such as foundations and superstructure were not considered.

The level of component detail was determined by the members of the maintenance steering committee. This level varied, depending on the facility classification and the costs versus the benefit of collecting and maintaining data. For example, in the typical building the steering committee voted to stop at the door level and not define hardware requirements because the hardware was not a costly item, but for historical family housing, where one hinge could cost $200, all door hardware had to be defined.

Task Data Development

A task is defined as the work performed by a single trade. Each task is divided into the labor, material, and equipment resources required to perform the work. By separating the tasks in this manner the data can also be used to determine manpower staffing requirements and equipment requirements. The following procedures have been used to develop the tasks for this research project. Identical procedures can be applied to develop new tasks not currently covered in the task data base.

The task development procedures can be demonstrated by using the existing task number 0811202, REPLACE WASHER IN BALL COCK OF WATER CLOSET, shown in Table 1. The task includes turning valve off and on; removing and installing rod lifter, valve, and washer; grinding valve seat; and checking operation.

The first step is to obtain a copy of DA Pamphlet 25-30, *Consolidated Index of Army Publications and Blank Forms*. A list of the current TBs covering EPS is given in Appendix C. Review this list to determine which TBs seem to address the task to be developed. The TBs can be obtained from your library or from:

Naval Publications and Forms Center
5801 Tabor Avenue
Philadelphia, PA 19120

Once the TBs are available, the second step is to review the Table of Contents of each to determine if tasks related to the component are covered in the bulletin. If the tasks to be developed are covered by the bulletin, review the tasks to determine if the data given can be applied to the task under development. When tasks related to the new component tasks under development are not covered by EPS, other sources such as estimating books and manuals, national standards, trade publications, and manufacturer data must be researched. It is important to provide a complete list of such materials. A reference librarian can provide resources addressing a specific component.

All labor hours were taken from the Pipefitting and Plumbing Handbook, TB-420-20, Table QT-314, page 183, as shown in Table 4.

Labor hours for turning the water valve on and off were in subtask 1. The time used is .00846, hr/job or .008.

Labor hours for removing and installing the tank cover were in subtask 2. The time used is .01726 hr/job or .01700.

Labor hours for removing and installing two screws were in subtask 3. The time used is .03508 hr/job or .03500.

Labor hours for removing and installing valve rod lifter were in subtask 4. The time used is .00396 hr/job or .00400.

Labor hours for removing and installing valve rod were in subtask 5. The time used is .00396 hr/job or .00400.

Labor hours for removing the damaged washer were in subtask 6. The time used is .02252 hr/job or .02300.

Labor hours for installing the new washer were in subtask 7. The time used is .01265 hr/job or .01300.

Table 4

Task QT-314*

No.	Reference	Work Unit Description	Hours	Units
1	PWQ-14-IV	Turn valve on and off	.00846	Job
2	PWMU-1-8012	Remove and install cover	.01726	Job
3	PWMU-1-8000	Remove and install two screws	.03508	Job
4	PWMU-1-8005	Remove and install valve rod lifter	.00396	Job
5	PWMU-1-8005	Remove and install valve rod	.00396	Job
6	PWMU-1-8013	Remove washer	.02252	Job
7	PWMU-1-8010	Install washer	.01265	Job
8	PWMU-1-8026	Grind valve seat	.01627	Job
9	4201	Check operation	.02400	Job

*** QT-314 = .14416 hr/job.**

Labor hours for grinding the valve seat were in subtask 8. The time used is .01627 hr/job or .01600.

Labor hours for checking operation of the reassembled water closet were in subtask 9. The time used is .02400 hr/job.

The total direct labor hours to perform the entire job would be the sum of all subtasks, or .144000 hr/job. The indirect time or the time to plan the work, load the truck at the beginning of the day, unload the truck at the end of the day, personal time, delay time, and material handling time must be included to obtain the total onsite labor time. In EPS, this value is expressed as a percentage of the direct labor. When all factors have been considered, the direct labor should be increased by 30 percent or .043200 hr/job.

The steering committee wanted to apply the same material costs for all planning, programming, design, construction, and operations activities. For this research project, all material costs were developed using prices in the Washington, DC area. Material prices for exact locations throughout the world can be obtained by multiplying the Washington, DC area costs by the appropriate location adjustment factor published in a Programming, Administration, and Execution System (PAX) Newsletter under the title "Area Cost Factor Indexes." Copies of the 22 September 1988 indexes are given in Appendix D, Geographical Location Adjustment Factors. The *CACES Unit Price Book* for Region II dated July 1, 1985 has been used for all costs and can be obtained from the Corps District Cost Estimating Section.

In reviewing material prices, there will usually be many grades listed for the component in question. Since only one entry for the component task will be made for the maintenance data base, it is important to use the middle grade for pricing. This will produce an average material cost.

When materials are not given in the CACES manuals, other material pricing manuals, such as Means, should be used to determine the cost.

The material cost for washers is obtained from local plumbing vendors and was quoted at $0.17/washer.

The normal equipment cost is for a maintenance truck with all required tools such as ladders and hand tools. The cost for the truck and equipment is usually based on task duration.

Task frequency determination is the most subjective area in the data base. Most frequencies must be determined by the judgment of professional maintenance personnel with many years of experience in performing the maintenance tasks. Some task frequencies are suggested by the manufacturer or professional organizations. Some frequencies, such as for interior wall painting, are set by regulations. There is very little published information in this area.

The data base has been reviewed by 10 installation Directorates of Engineering and Housing (DEHs) and has been determined to accurately represent the resources required to perform the tasks. This data base serves as the foundation for the tables published in this report. The complete data base is too large to be duplicated in this report, but is available in the USACERL Special Report series titled *Maintenance Task Data Base for Buildings.*

The maintenance steering committee asked Forts Leonard Wood and Bragg to use the tasks to produce resource estimates for the past 3 years and then compare the predictions with their actual expenditures on a facility-by-facility basis. After this comparison was performed by both installations, the results were presented to the steering committee. Both installations stated they were not performing all the tasks they should, such as annual gutter cleaning and annual roof inspection. For the total installation, the tasks predicted an 8 to 10 percent higher total expenditure than the actual expenditure. This difference was due to the difference between the tasks predicted and actually performed. When comparisons were made at the task level, the task resource predictions were found to be accurate.

Two additional reviews were performed by two independent organizations that had related research work in the Army. The first review was for a research project to determine the maintenance requirements for historical family housing within the Military District of Washington, DC. The second review was a research project which needed an estimate of all resource requirements for the entire Army. This effort is known as the RPLANS research project. Both organizations reviewed the data base in detail and approved the resource requirements stated in the tasks. In addition, both used the data base within their research projects.

Significance of the Task Data

The task data presented in the previous section is based on average resources. Actual resource values for a particular project will vary as discussed below.

The labor hours reported will vary, depending on factors such as the actual productivity of the workers, the weather conditions, and the working space available. The labor hours given in this report are based on the average obtained from performing time and motion studies as tasks were performed.

The Washington, DC, material costs will vary, depending on factors such as the grade of material actually used, the manufacturer, and the quantity of material actually purchased. The figures given are the averages for all material prices found in the unit price books.

Task frequencies are the most subjective feature in the data base. High, average, and low frequency values are given to emphasize the variances. Average frequencies are used in developing the life-cycle analysis tables presented in the following sections.

Component Summary Tables

A typical component summary is shown in Table 2 (Chapter 1). The development process is illustrated by using the labor resource for the flush tank water closet component.

All tasks related to the flush tank component are listed individually in Table 5, with a task summary in Table 6. The task average frequency is used to project times of occurrence of M&R tasks for the first 25-year period as shown in Table 7.

The first task (Task 1 - 0811201 -Unplug clogged line) has an average frequency (AVE FREQ in Table 6) of 5 years; thus, it would be performed every 5 years. The labor hours (1.582100 in Table 6) are listed for every 5 years of the 25 years in the second column of Table 7.

The second task (Task 2 - 0811202 - replace washer in ball cock) has an average frequency from Table 6 of 5 years; thus, it would be performed once every 5 years. The labor hours (.187200 in Table 6) are listed for the years 5, 10, 15, 20, and 25 in the third column of Table 7.

The third task (Task 3 - 0811203 - replace worn parts) has an average frequency of 15 years; thus it would be performed every 15 years. The labor hours (1.210300 in Table 6) are listed for the fifteenth year in the fourth column of Table 7.

The fourth task (Task 4 - 0811204 - install gasket in spud connection) has an average frequency of 20 years; thus, it would be performed once every 20 years. The labor hours (.113900) are listed for year 20, in the fifth column of Table 7.

The fifth task (Task 5 - 0811205 - replace water closet) has an average frequency of 35 years; thus, it would be performed every 35 years, 10 years beyond the 25 year study period. No entries are made in column 6.

The total column in Table 7 is formed by adding the labor hours for Tasks 1 through 5 on a year-by-year basis. For example, during the fifth year, Tasks 1, 2, and 6 are performed. The total labor hours would be 1.582100 + .187200 which equals 1.769300.

The total column in Table 7 is shown in Table 2, a typical component summary for a flush tank water closet—081120. The material costs and equipment hours have been developed in the same manner as explained for the labor hours.

Table 5

Tasks for a Flush Tank Water Closet

TASK DATA FORM

Task Code: 0811201

Component: FLUSH-TANK WATER CLOSET System: SANITARY Subsystem: FIXTURES
Task Description: M/R UNPLUG CLOGGED LINE
Unit of Measure: COUNT Frequency of Occurrence: M: 3.00 A: 5.00 L: 7.00
Persons per Team: 1 Task Duration: 1.5821 hours Once every (M,A,L) years
Trade: PLUMBING Task Classification: 0

Labor Resources

Subtask Description	Labor Hrs
1.TURN VALVE OFF AND ON	0.008000
2.REMOVE PACKING NUTS	0.109000
3.REMOVE/INSTALL NUTS FROM BOLTS	0.070000
4.REMOVE BOWL FROM FLANGE/INSTALL	0.194000
5.REMOVE GASKET	0.009000
6.UNPLUG LINE	0.150000
7.INSTALL GASKET	0.023000
8.APPLY PUTTY	0.132000
9.CLEAN PUTTY/BOWL FOUNDATION	0.136000
10.CONNECT PACKING NUTS	0.115000
11.CHECK OPERATION	0.167000
12.MOVE MATERIAL	0.104000

Material Resources

Description	Quantity	Unit Cost
PUTTY	6 oz	0.2200
		1.3200

SUMMARY

Resources	UOM	Direct	Indirect	Total
Labor	Hours	1.217000	0.365100	1.582100
Material	Cost $	1.320000		1.320000
Equipment	Hours			1.582100

Components In This Task: 0811200

Table 5 (Cont'd)

TASK DATA FORM

Task Code: 0811202

Component: FLUSH-TANK WATER CLOSET System: SANITARY Subsystem: FIXTURES
Task Description: M/R REPLACE WASHER IN BALL COCK
Unit of Measure: COUNT Frequency of Occurrence: H: 4.00 A: 5.00 L: 6.00
Persons per Team: 1 Task Duration: 0.1872 hours Once every (H,A,L) years
Trade: PLUMBING Task Classification: 0

Labor Resources

Subtask Description	Labor Hrs
1.TURN VALVE ON AND OFF	0.008000
2.REMOVE AND INSTALL COVER	0.017000
3.REMOVE AND INSTALL 2 SCREWS	0.035000
4.REMOVE/INSTALL VALVE ROD LIFTER	0.004000
5.REMOVE AND INSTALL VALVE ROD	0.004000
6.REMOVE WASHER	0.023000
7.INSTALL WASHER	0.013000
8.GRIND VALVE SEAT	0.016000
9.CHECK OPERATION	0.024000

Material Resources

Description	Quantity	Unit Cost
WASHER	1	0.1700
		0.1700

SUMMARY

Resources	UOM	Direct	Indirect	Total
Labor	Hours	0.144000	0.043200	0.187200
Material	Cost $	0.170000		0.170000
Equipment	Hours			0.187200

Components in This Task: 0811200

TASK DATA FORM

Task Code: 0811203

Component: FLUSH-TANK WATER CLOSET System: SANITARY Subsystem: FIXTURES
Task Description: M/R REPLACE WORN PARTS IN WATER CLOSET
Unit of Measure: COUNT Frequency of Occurrence: H: 13.00 A: 15.00 L: 17.00
Persons per Team: 1 Task Duration: 1.2103 hours Once every (H,A,L) years
Trade: PLUMBING Task Classification: 0

Labor Resources

Subtask Description	Labor Hrs
1.TURN VALVE OFF AND ON	0.008000
2.REMOVE AND INSTALL COVER	0.017000
3.REMOVE/INSTALL FLOAT ON ROD	0.018000
4.REMOVE/INSTALL FLOAT ROD	0.025000
5.REMOVE AND INSTALL FLOAT VALVE	0.077000
6.CLEAN VALVE SEAT	0.067000
7.REMOVE/INSTALL LOCK NUT	0.021000
8.REMOVE WASHER ON FLOAT VALVE	0.013000
9.INSERT WASHER ON FLOAT VALVE	0.013000
10.REMOVE/INSTALL ROD IN BALL	0.025000
11.REMOVE AND INSTALL LIFT ROD	0.025000
12.REMOVE/INSTALL RUBBER BALL	0.077000
13.REMOVE/INSTALL FLUSH PIPE NUTS	0.043000
14.REMOVE/INSTALL LOCK NUTS	0.043000
15.INSTALL RUBBER GASKETS	0.048000
16.ADJUST PARTS	0.188000
17.CHECK OPERATION	0.167000
18.REMOVE/INSTALL SUPPLY SLIP NUT	0.021000
19.MOVE MATERIAL	0.035000

Material Resources

Description	Quantity	Unit Cost
REPAIR KIT	1	15.5000
		15.5000

SUMMARY

Resources	UOM	Direct	Indirect	Total
Labor	Hours	0.931000	0.279300	1.210300
Material	Cost $	15.500000		15.500000
Equipment	Hours			1.210300

Components in This Task: 0811200

Table 5 (Cont'd)

TASK DATA FORM

Task Code: 0811204

Component: FLUSH-TANK WATER CLOSET System: SANITARY Subsystem: FIXTURES
Task Description: N/R INSTALL GASKET IN SPUD CONNECTION
Unit of Measure: COUNT Frequency of Occurrence: H: 17.00 A: 20.00 L: 23.00
Persons per Team: 1 Task Duration: 0.1339 hours Once every (H,A,L) years
Trade: PLUMBING Task Classification: 0

Labor Resources

Subtask Description	Labor Hrs
1.TURN VALVE OFF AND ON	0.017000
2.LOOSEN LOCKNUT	0.011000
3.REMOVE SPUD CONNECTION	0.013000
4.REMOVE GASKET OR WASHER	0.013000
5.CLEAN SPUD SEAT	0.016000
6.INSTALL NEW GASKET OR WASHER	0.002000
7.INSTALL SPUD CONNECTION	0.013000
8.TIGHTEN LOCKNUT	0.011000
9.INSPECT CONNECTION	0.007000

Material Resources

Description	Quantity	Unit Cost
GASKET	1	0.1200
		0.1200

SUMMARY

Resources	UOM	Direct	Indirect	Total
Labor	Hours	0.103000	0.030900	0.133900
Material	Cost $	0.120000		0.120000
Equipment	Hours			0.133900

Components In This Task: 0811200

TASK DATA FORM

Task Code: 0811205

Component: FLUSH-TANK WATER CLOSET System: SANITARY Subsystem: FIXTURES
Task Description: REPLACE REPLACE WATER CLOSET
Unit of Measure: COUNT Frequency of Occurrence: H: 26.00 A: 35.00 L: 44.00
Persons per Team: 2 Task Duration: 2.0560 hours Once every (H,A,L) years
Trade: PLUMBING Task Classification: 1

Labor Resources

Subtask Description	Labor Hrs
1.TURN WATER OFF AND ON	[illegible]
2.REMOVE SEAT NUTS	0.021000
3.REMOVE SEAT	0.026000
4.DISCONNECT FLUSH PIPE	0.073000
5.DISCONNECT FEED LINE	0.011000
6.REMOVE LAG SCREWS	0.021000
7.REMOVE TANK FROM WALL	0.026000
8.REMOVE STOOL NUTS FROM BOLTS	0.043000
9.REMOVE BOWL	0.097000
10.BOLTS FROM RING	0.043000
11.REMOVE GASKET	0.023000
12.INSTALL NEW BOWL AND TANK	2.568000
13.MOVE MATERIAL	0.207000

Material Resources

Description	Quantity	Unit Cost
WATER CLOSET	1	74.5900
		74.5900

SUMMARY

Resources	UOM	Direct	Indirect	Total
Labor	Hours	3.163000	0.948900	4.111900
Material	Cost $	74.590000		74.590000
Equipment	Hours			2.055950

Components In This Task: 0811200

Table 6

Tasks Summary Data for a Flush Tank Water Closet

Army Wide Task/Basic Task Structure List   Tree id: BF   Group id: B5

UM = Unit of Measure   TRD = Trade Index Class = Task Classification   TWPMTH = Task Work Performance Method

CACES	DESCRIPTION	UM	TRD	CLASS	HIGH FREQ	AVE FREQ	LOW FREQ	LABOR HOURS	MATERIAL COSTS	EQUIPMENT HOURS
	081120 FLUSH TANK WATER CLOSET									
081120	UNPLUG CLOGGED LINE	1	3	0	3.00	5.00	7.00	1.582100	1.320000	1.582100
0811202	REPLACE WASHER IN BALL COCK	1	3	0	4.00	5.00	6.00	.187200	.170000	.187200
0811203	REPLACE WORN PARTS IN WATER CLOSET	1	3	0	13.00	15.00	17.00	1.210300	15.500000	1.210300
0811204	INSTALL GASKET IN SPUD CONNECTION	1	3	0	17.00	20.00	23.00	.133900	.120000	.133900
0811205	REPLACE WATER CLOSET	1	3	1	26.00	35.00	44.00	4.111900	74.590000	2.055950

Table 7

Flush Tank Water Closet Spreadsheet - Labor Hours

Year	Task 1	Task 2	Task 3	Task 4	Task 5	Total	10%	P.W. LABOR
1						0.000000	0.7164	0.000000
2						0.000000	0.6512	0.000000
3						0.000000	0.5920	0.000000
4						0.000000	0.5382	0.000000
5	1.582100	0.187200				1.769300	0.4893	0.865718
6						0.000000	0.4448	0.000000
7						0.000000	0.4044	0.000000
8						0.000000	0.3676	0.000000
9						0.000000	0.3342	0.000000
10	1.582100	0.187200				1.769300	0.3038	0.537513
11						0.000000	0.2762	0.000000
12						0.000000	0.2511	0.000000
13						0.000000	0.2283	0.000000
14						0.000000	0.2075	0.000000
15	1.582100	0.187200	1.210300			2.979600	0.1886	0.561953
16						0.000000	0.1715	0.000000
17						0.000000	0.1559	0.000000
18						0.000000	0.1417	0.000000
19						0.000000	0.1288	0.000000
20	1.582100	0.187200		0.113900		1.883200	0.1171	0.220523
21						0.000000	0.1065	0.000000
22						0.000000	0.0968	0.000000
23						0.000000	0.0880	0.000000
24						0.000000	0.0800	0.000000
25	1.582100	0.187200				1.769300	0.0727	0.128628
							TOTAL	2.314335

The component data base is not printed in this report because of its size. Component summary data tables are published in the USACERL Special Report series titled *Maintenance Component Data Base for Buildings*.

Life-Cycle Cost Analysis Tables

The main purpose of this report is to provide the designer with easy-to-use tables for the most common life-cycle cost analysis. USACE designers frequently perform life-cycle cost analysis for a 25-year period using a 7 or 10 percent discount rate shown in Tables 8 and 9. Two sets of summary tables have been generated for these cases and are given in Appendices A and B. Table 3 shows typical life-cycle cost analysis data.

Present Worth. The left four columns of Table 3, labeled "Present Worth of All 25-Year Maintenance and Repair Costs," were developed by multiplying the resources in Table 2 by the 7 or 10 percent present worth factors shown in Tables 8 and 9. The 25 individual year resource figures are totaled as shown for labor in Table 7.

The 1988 Washington, DC area labor and equipment rates were applied to this data to produce the totals shown in the column so titled. This column is given to provide one comparative cost figure for easy computation. This column can be used to quickly assess the ranking of various components' total 25-year LCC.

Annual and High Cost. The right section of Table 3 is provided as input data for current life-cycle cost analysis computer programs. Two types of input are usually required: (1) a uniform or annual maintenance figure and (2) high-cost and replacement tasks that occur in specific years.

The data listed under the heading "Annual Maintenance and Repair" was generated by subtracting the present worth of the replacement task, if its occurrence is 25 years or less, and any high-cost tasks from the present worth values given in the "Present Worth" section of the table. The remaining present worth figures for the low-cost task resources are divided by the cumulative 25-year present worth figure to arrive at the "uniform" or "annual" maintenance figures shown under the "Annual Maintenance and Repair" heading.

There are two types of tasks listed under the heading "Replacement and High-Cost Tasks." The first is the replacement task. The replacement task is shown on the same line as the component description. For example, the replacement task for Urinals shown in Table 3 would occur when the urinal is 35 years old. Replacement would require the expenditure of 2.1333 hours of labor per unit, $167.48 of material per unit, and 1.06665 hours of equipment (maintenance truck) per unit. The second type of task is the high-cost task. Each high-cost task is listed on a separate line below the component description line. There is no example of this here. High cost tasks are figured in the same manner as replacement tasks.

Table 8

7 Percent Discount Factors From Date of Study*

Years from BOD	End of Year	Accumulated End of Year
1	0.9346	0.9346
2	0.8734	1.8080
3	0.8163	2.6243
4	0.7629	3.3872
5	0.7130	4.1002
6	0.6663	4.7665
7	0.6227	5.3893
8	0.5820	5.9713
9	0.5439	6.5152
10	0.5083	7.0236
11	0.4751	7.4987
12	0.4440	7.9427
13	0.4150	8.3576
14	0.3878	8.7455
15	0.3624	9.1079
16	0.3387	9.4466
17	0.3166	9.7632
18	0.2959	10.0591
19	0.2765	10.3356
20	0.2584	10.5940
21	0.2415	10.8355
22	0.2257	11.0612
23	0.2109	11.2722
24	0.1971	11.4693
25 (Retention value at end of 25th year)	0.1842	11.6536

*Date of Study (DOS) is the Beneficial Occupancy Date (BOD)

Table 9

10 Percent Discount Factors From Date of Study*

	Factors		
Year from BOD	Mid-Year	End of Year	Accumulated Mid-Year
-3	0.9535		0.0
-2	0.8668		0.0
-1	0.7880		0.0
BOD			
1	0.7164		0.7164
2	0.6512		1.3676
3	0.5920		1.9596
4	0.5382		2.4978
5	0.4893		2.9871
6	0.4448		3.4319
7	0.4044		3.8362
8	0.3676		4.2038
9	0.3342		4.5380
10	0.3038		4.8418
11	0.2762		5.1180
12	0.2511		5.3691
13	0.2283		5.5973
14	0.2075		5.8048
15	0.1886		5.9935
16	0.1715		6.1650
17	0.1559		6.3209
18	0.1417		6.4626
19	0.1288		6.5914
20	0.1171		6.7086
21	0.1065		6.8150
22	0.0968		6.9118
23	0.0880		6.9998
24	0.0800		7.0799
25	0.0727		7.1526
Retention Value at End of 25th Year		0.0693	

*Date of Study (DOS) is exactly 3 years before the Beneficial Occupancy Date (BOD).

4 DATA BASE APPLICATION EXAMPLES

Introduction

This chapter is divided into two sections. The first section defines the terminology used in the report and information needed to apply the labor hour, material cost and equipment hour resource data in this report. The second section gives specific examples using both the 10 percent present worth tables given in Appendix B and the 7 percent present worth tables given in Appendix A.

Terminology

Economic Studies

Two basic types of economic studies are covered in this report: (1) general economic studies and (2) special energy-conservation studies.

General economic studies are conducted routinely as part of the design process for all military facilities. Such studies are normally performed for a 25-year period using a 10 percent discount rate and considering tasks to be performed mid-year. The Beneficial Occupancy Date (BOD) occurs approximately three years after the Date of Study (DOS) for most MILCON projects, and that is what is assumed in the example provided herein.

Special economic studies for the design of energy-consuming portions of a building are required by statute. Such studies analyze the use of extraordinary energy-saving design initiatives to conserve energy in new Federal facilities. The studies are normally performed for a 25-year period using a 7 percent discount rate considering all tasks to be performed at the end of the year. The BOD is normally assumed to occur on the DOS, in accordance with the provisions of the design criteria.

Installation Labor Rates

To perform an accurate cost analysis, the current shop effective labor rates and equipment rates per hour must be obtained from the installation. This information can be obtained from the DEH. Telephone numbers for the DEH are listed in the "Director of Engineering and Housing/Facilities, Engineer Assignments Roster" published yearly by the Office of the Chief of Engineers. Most installations maintain this information within their IFS data base; it can be obtained from the IFS data base administrator within the Management Engineering and Systems Branch.

Initial Costs

The initial construction costs can be obtained from the CACES Regional Unit Cost Manuals. The manuals are available from the district cost estimating section. When this manual is not available the cost estimates can be taken from other publications such as Means and Dodge.

Geographical Location Adjustment Factors

The Washington, DC-based material costs in the summary tables can be adjusted to a specific installation through the application of a geographical location adjustment factor. The factors are published

in AR 415-17 and updates are available through the PAX computer system (Area Cost Factor Newsletter) and through the Engineering Improvement Recommendation System (EIRS) Bulletin. The 1988 set of factors is given in Appendix D.

Inflation Factors

The material costs and Washington, DC, total costs presented in Appendices A and B are in July 1988 dollars. The costs need to be adjusted to the date of study by applying an approved inflation factor obtained from the District cost estimating office.

Timing of Costs

Figure 1 shows the relationship of DOS, BOD, and the end of the study (EOS) which is assumed to be a 25-year comparison period:

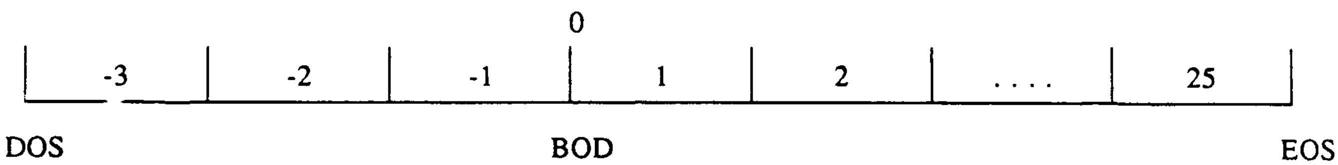

Figure 1. DOS, BOD, EOS relationship.

In Appendix B, costs are discounted 3 years from time of occurrence to DOS. M&R costs occur throughout a year and are costed at mid-year in accordance with established criteria for MILCON design. The basic present worth factor formula is:

$$PWF(BA) = \frac{1}{(1 + DR)^{(B + BA - C)}} \quad \text{[Eq 1]}$$

where PWF = present worth factor
BA = building age
DR = discount rate
B = years from DOS to BOD
C = task placement, either .5 for mid-year, or 0 for end of year

The 10 percent present worth factor to bring costs from the mid-year of first year of occupancy to the DOS is $1/(1.1)^{3.5} = 0.7164$ which is the first value in Table 9. If the DOS is not 3 years before BOD, Appendix B data can be adjusted. For example, if there is only 1 year between BOD and DOS (two less than the 3 years in the appendices), multiply this data by $(1.1)^2$. If there are 5 years (2 years more than the 3 years in the appendices), divide by $(1.1)^2$.

In Appendix A, the DOS and BOD are identical. M&R costs are assumed to occur at the end of the year as stipulated by regulations. The basic formula is:

$$PWF(BA) = \frac{1}{(1 + DR)^{(BA)}} \quad \text{[Eq 2]}$$

where PWF = present worth factor
BA = building age
DR = discount rate

Disposal Costs/Retention Value

When disposal costs/retention value is considered, it should be expressed as a percentage of the initial cost occurring at the end of the study period. The present worth of this value can be subtracted from the final net present worth.

Examples

Introduction

This section contains one example for each of the basic uses for this life-cycle cost data. The first example demonstrates the procedures for calculating LCC for construction and maintenance and repair when the DOS is exactly 3 years before the BOD, the building is 25 years old at the end of the study and installation resource costs are available from the installation. The second example also has BOD 3 years after DOS. The third example demonstrates the procedures for calculating LCC for construction and maintenance and repair when resource costs are not available from the installation and Washington, DC, cost data is to be applied. Examples 4 and 5 show how to adjust data to cover the case for which BOD is not 3 years after DOS. Example 6 shows how to use the data to generate input for other computer programs. Example 7 demonstrates the use for a project containing an extraordinary energy-saving design initiative to conserve energy.

Each example is presented in five sections:

1. Statement of the problem.

2. Identification of all installation-related information.

3. Identification of all component-related information.

4. Description of the present worth calculations.

5. A typical calculation worksheet.

Example 1: BOD 3 Years After DOS--Flush Tank Water Closet

Problem Statement. This example demonstrates all steps using a system of Flush Tank Water Closets with 10 units. An apartment building for family housing is under design at Fort Eustis, VA. The DOS is July 1989. The projected BOD is July 1992. A 25-year life-cycle cost analysis using a 10 percent discount rate is required.

Installation-Related Data.

Geographic Location Adjustment Factor. The geographic location adjustment factor (LAF) can be obtained from the latest EIRS bulletin or from the Area Cost Factor Newsletter on the PAX computer

system, as shown in Appendix D. The factors are indexed by state and then by location within the state. From Appendix D, for Virginia and Fort Eustis, the geographic LAF (or Area Cost Factor [ACF] Index) is 0.96.

Inflation. The cost data in Appendix B is expressed in July 1988 dollars. Since the date of the study is July 1989, all cost figures must be adjusted. A telephone conversation with a District cost estimator has revealed that the costs have risen 2 percent from July 1988 to July 1989. This means that all costs need to be multiplied by a 1.02 cost adjustment factor.

Resource Rates. The labor and equipment resources in Appendix B are expressed in hours per unit measure. To obtain accurate cost figures the designer called the Fort Eustis DEH-MES branch. The July 1989 rates of $13.50 per hour for a Plumber and $3.00 per hour for a Plumber maintenance truck were obtained.

Component Information.

Size. The designer is considering a system of Flush Tank Water Closets composed of ten units.

Initial Costs. The designer obtained a CACES unit price manual from the cost estimator. For the Water Closet component, a cost of $79.06 per unit was obtained. (Note: if the component is not found in the *CACES Unit Price Manual*, other books such as Means and Dodge can be used.)

Retention Value. The average life of a Flush Tank Water Closet is 35 years for the replacement task in Appendix B. At the end of the 25-year analysis period, the Water Closet would still have 10 years of life remaining or 10/35 = 29 percent of its useful life. The retention value is 29 percent of the initial cost of $79.06 per Unit, or $22.9274 per Unit.

Present Worth Calculations. Three factors must be considered when performing a present worth calculation: initial cost, maintenance costs, and retention value. Each factor is discussed below.

Initial Costs. The average construction project would normally be completed in 1 year. The contractor normally receives progress payments for work completed throughout the construction period. The initial cost of $79.06/per unit is assumed to occur at the midpoint of construction during the year before BOD. The present worth factor at midyear for the year before BOD is given in Table 9 as 0.7880. The present worth of the initial cost would be the initial cost multiplied by the present worth factor at BOD or $79.06/unit x 0.7880 = $62.30/unit.

25-Year Maintenance Cost. The total 25-year maintenance cost is composed of three parts: labor, material, and equipment. Labor costs per unit are equal to the labor hours per unit obtained from Appendix B, multiplied by the installation labor hourly rate. This would be 2.31668 hr/unit multiplied by a labor rate of $13.50/hr, which is equal to $31.28/unit.

$$\text{Labor} = 2.31668 \text{ hours/unit} \times \$13.50/\text{hr} = \$31.28/\text{unit} \quad \text{[Eq 3]}$$

Material costs per unit are equal to the material dollars in Washington, DC, base per unit obtained from Appendix B, multiplied by the geographic LAF from Appendix D and then multiplied by the inflation factor. This would be $4.96386 DC-based dollars per unit multiplied by a geographic LAF of 0.96 and a cost escalation factor (CEF) of 1.02 which is equal to $4.86/Unit.

$$\text{Material} = \$4.96386/\text{unit} \times 0.96 \times 1.02 = \$4.86/\text{unit} \qquad \text{[Eq 4]}$$

Equipment costs per unit are equal to the equipment hours per unit obtained from Appendix B, multiplied by the installation equipment hourly rate. This would be 2.31668 hr/unit multiplied by an equipment rate of $3.00/hr which is equal to $6.95/unit.

$$\text{Equipment} = 2.31668 \text{ hr/unit} \times \$3.00/\text{hr} = \$6.95/\text{unit} \qquad \text{[Eq 5]}$$

The total maintenance cost per unit would be the labor cost ($31.28/unit) plus the material cost ($4.86/unit) plus the equipment cost ($6.95/unit) or $43.09/unit.

$$\text{Total} = \$31.28/\text{unit} + \$4.86/\text{unit} + \$6.95/\text{unit} = \$43.09/\text{unit} \qquad \text{[Eq 6]}$$

This total has already been discounted to the DOS since all figures on the left side of the table in Appendix B are expressed in terms of the DOS.

Retention Value. The DOS present worth for the retention value would be the expected retention value of $22.92740/unit multiplied by the end-of-year present worth factor for the end of study year (EOS) obtained from Table 9, 0.06930, which produces a cost of $1.59/unit.

Total Life Cycle Cost for Construction and Maintenance and Repair. The total life-cycle cost (LCC) per unit for the DOS is the sum of the present worth costs for the initial cost of $62.30/unit plus the 25-year maintenance cost of $43.09/unit minus the retention of $1.59/unit.

$$\text{Total LCC} = \$62.30 + \$43.09 - \$1.59 = \$103.80 \text{ unit} \qquad \text{[Eq 7]}$$

The total dollar cost would be the LCC per unit of $103.80 multiplied by the 10 units producing a total cost of $1038.00.

Calculation Sheet. A typical calculation sheet is shown in Table 10.

Example 2: BOD 3 Years After DOS—Urinal

Problem Statement. This example demonstrates all steps using a system of ten urinals. A Bachelor Officers Quarters is under design at Fort Eustis, VA. The DOS is July 1989. The projected BOD is July 1992, 3 years after DOS. A 25-year LCC analysis using a 10 percent mid-year discount rate is required.

Installation Related Data.

Geographic location adjustment factor. The geographic LAF can be obtained from the latest EIRS bulletin on the PAX computer system as shown in Appendix D. The factors are indexed by state and then by location within the state. From Appendix D for Virginia and Fort Eustis, the geographic LAF (or ACF Index) is 0.96.

Inflation. The cost data in Appendix B is expressed in July 1988 dollars. Since the DOS is July 1989, all cost figures must be adjusted. A telephone conversation with a District cost estimator has revealed that the costs have risen 2 percent from July 1988 to July 1989. This means that all costs need to be multiplied by a 1.02 cost adjustment factor.

Table 10

Calculation Sheet - Example 1

	Calculation Column	Subfactor Cost/Unit	Factor Cost/Unit	Total Cost
Initial Cost				
Initial Cost	$79.06/unit			
PWF for BOD-1	x .7880			
Initial cost/unit			$62.30/unit	
25-Year Maintenance Cost				
PW - Labor	2.31668 hr/unit			
Labor Rate	x $13.50/hr			
Labor cost/unit		$31.28/unit		
PW - Material	$4.96386/unit			
LAF	x .96			
CEF	x 1.02			
Material cost/unit		$4.86/unit		
PW - Equipment	2.31668 hr/unit			
Equipment Rate	x $3.00/hr			
Equipment cost/unit		$6.95/unit		
Maintenance cost/unit			$43.09/unit	
Retention Value				
Initial Cost	$79.06/unit			
Remaining Life	x .29			
PWF for EOS	x .06			
Retention Value cost/unit			$1.59/unit	
Life-Cycle Cost/unit			$103.80/unit	
Unit			x 10 unit	
TOTAL Life-Cycle Cost				$1038.00

Resource Rates. The labor and equipment resources in Appendix B are expressed in hours per unit measure. To obtain accurate cost figures the designer called the Fort Eustis DEH-MES branch. The July 1989 rates for a plumber, $13.50/hr and the plumber maintenance truck, $3.00/hr, were obtained.

Component Information.

Size. The designer is considering a plumbing system with ten urinals.

Initial Costs. The designer obtained a *CACES Unit Price Manual* from the cost estimator. For the urinal component, a cost figure of $167.48/unit was obtained. (Note: if the component is not found in the *CACES Unit Price Manual*, other books such as Means and Dodge can be used.)

Retention Value. The average life of a urinal is 35 years as shown for the replacement table in Appendix B. At the end of the 25-year analysis period, the urinal would still have 10 years of life remaining or 10/35 = 29 percent of its useful life. The retention value can be considered to be 29 percent of the initial cost of $167.48/unit or $48.57/unit.

Present Worth Calculations. Three factors need to be considered when performing a present worth calculation: initial cost, maintenance costs, and retention value. Each factor is discussed below.

Initial Costs. The average construction project would normally be completed in 1 year. The contractor normally receives progress payments for work completed throughout the construction period. The initial cost of $167.48/per unit is assumed to occur at the midpoint of construction during the year before BOD. The present worth factor at midyear for the year before BOD is given in Table 9 as 0.7880. The present worth of the initial cost would be the initial cost multiplied by the present worth factor at BOD or $167.48/unit x 0.7880 = $131.97/unit.

25-Year Maintenance Cost. The total 25-year maintenance cost is composed of three parts: labor, material, and equipment. Labor costs per unit are equal to the labor hours per unit obtained from Appendix B multiplied by the installation labor hourly rate. This would be 2.89694 hr/unit multiplied by a labor rate of $13.50/hr which is equal to $39.11/unit.

$$\text{Labor} = 2.89694 \text{ hr/unit} \times \$13.50/\text{hr} = \$39.11/\text{unit} \qquad \text{[Eq 8]}$$

Material costs per units are equal to the material dollars in Washington, DC, base per unit obtained from Appendix B, multiplied by the geographic LAF from Appendix D and then multiplied by the inflation factor. This would be $10.98923 DC based dollars per unit multiplied by a geographic LAF of 0.96 and a CEF of 1.02 which is equal to $10.76/unit.

$$\text{Material} = \$10.98923/\text{unit} \times 0.96 \times 1.02 = \$10.76/\text{unit} \qquad \text{[Eq 9]}$$

Equipment costs per unit are equal to the equipment hours per unit obtained from Appendix B, multiplied by the installation equipment hourly rate. This would be 2.89694 hr/unit multiplied by an equipment rate of $3.00/hr which is equal to $8.69/unit.

$$\text{Equipment} = 2.89694 \text{ hr/unit} \times \$3.00/\text{hr} = \$8.69/\text{unit} \qquad \text{[Eq 10]}$$

The total maintenance cost per unit would be the labor cost ($39.11/unit) plus the material cost ($10.76/unit) plus the equipment cost ($8.69/unit), or $58.56/unit.

$$\text{Total} = \$39.11/\text{unit} + \$10.76/\text{unit} + \$8.69/\text{unit} = \$58.56/\text{unit} \qquad \text{[Eq 11]}$$

This total has already been discounted to the DOS since all figures on the left side of the table in Appendix B are expressed in terms of the DOS.

Retention Value. The DOS present worth for the retention value would be the expected retention value, $48.57/unit, multiplied by the end of year present worth factor for the EOD obtained from Table 9, 0.0693, which produces a cost of $3.37/unit.

Total Life Cycle Cost for Construction and Maintenance and Repair. The total LCC per unit for the DOS is the sum of the present worth costs for the initial cost of $131.97/unit plus the 25-year maintenance cost of $58.56016/unit minus the retention value of $3.37/unit.

Total LCC = $131.97/unit + $58.56/unit - $3.37/unit = $187.16/unit [Eq 12]

The total dollar cost would be the LCC per unit, $187.16, multiplied by the ten units, producing a total cost of $1,871.60.

Calculation Sheet. A typical calculation sheet is shown in Table 11.

Table 11

Calculation Sheet - Example 2

	Calculation Column	Subfactor Cost/Unit	Factor Cost/Unit	Total Cost
Initial Cost				
Initial Costs	$167.48/unit			
PWF for BOD-1	x .7880			
Initial Costs/unit			$131.97/unit	
25-Year Maintenance Cost				
PW - Labor	2.89694 hr/unit			
Labor Rate	x $13.50/hr			
Labor cost/unit		$39.11		
PW - Material	$10.9823/unit			
LAF	x .96			
CEF	x 1.02			
Material cost/unit	$10.76			
PW - Equipment	2.89694 hr/unit			
Equipment Rate	x $3.00/hr			
Equipment cost/unit	$8.69			
Maintenance Cost/unit		$58.56		
Retention Value				
Initial Cost	$167.98/unit			
Remaining Life	x 0.29			
PWF for EOS	x .06930			
Retention value/unit		$3.37		
Life-Cycle Cost/unit			$187.16	
Units			x 10 units	
Total Life-Cycle Cost				$1871.60

Example 3: BOD 3 Years After DOS - Washington, DC Rate Applied

Problem Statement. This example demonstrates all steps using a system of ten flush tank, water closets. An apartment building for family housing is under design at Fort Eustis, VA. The DOS is July 1989. The projected BOD is July 1992, 3 years after DOS. A 25-year life-cycle cost analysis using a 10 percent mid-year discount rate is required.

The designer wishes to perform a rough cost estimate without calling the installation to obtain cost information. It should be understood that the installation's costs may vary significantly from the Washington, DC, costs and the rough calculations may be misleading. However, if the designer is going to compare two types of components such as tankless and flush tank water closets--both which involve the identical trade such as a plumber—the comparisons may be quite accurate.

Installation-Related Data.

Geographic Location Adjustment Factor. The geographic LAF can be obtained from the latest EIRS bulletin or from the Area Cost Factor Newsletter on the PAX computer system as shown in Appendix D. The factors are indexed by state and then by location within the state. From Appendix D, for Virginia and Fort Eustis, the geographic LAF (or ACF Index) is 0.96.

Inflation. The cost data in Appendix B is expressed in July 1988 dollars. Since the DOS is July 1989, all cost figures must be adjusted. A telephone conversation with a District cost estimator has revealed that the costs have risen 2 percent from July 1988 to July 1989. This means that all costs need to be multiplied by a 1.02 cost adjustment factor.

Resource Rates. The designer wishes to perform a rough calculation using the Washington, DC, labor and equipment rates rather than calling the installation.

Component Information.

Size. The designer is considering a system of ten flush tank water closets.

Initial Costs. The designer obtained a *CACES Unit Price Manual* from the cost estimator. For the flush tank component, a cost figure of $79.06/unit was obtained. (Note: if the component is not found in the *CACES Unit Price Manual*, other books such as Means and Dodge can be used.)

Retention Value. The average life of a unit is 35 years, as shown for the replacement task in Appendix B. At the end of the 25-year analysis period, the unit would still have 10 years of life remaining or 10/35 = 29 percent of its useful life. The retention value is 29 percent of the initial cost of $79.06/ unit or $22.92740/ unit.

Present Worth Calculations. Three factors need to be considered when performing a present worth calculation: initial cost, maintenance costs, and retention value. Each factor is discussed below.

Initial Costs. The average construction project would normally be completed in 1 year. The contractor normally receives progress payments for work completed throughout the construction period. The initial cost of $79.06/unit is assumed to occur at the midpoint of construction during the year before BOD. The present worth factor at midyear for the year before BOD is given in Table 9 as 0.7880. The

present worth of the initial cost would be the initial cost multiplied by the present worth factor at BOD or \$79.06/unit x 0.7880 = \$62.30/unit.

25-Year Maintenance Cost. The total 25-year maintenance cost for Fort Eustis can be calculated by taking the Washington, DC, total cost unit, \$54.05, and multiplying by the location adjustment factor (0.96) producing a cost of \$51.89/unit.

Retention Value. The DOS present worth for the retention value would be the expected retention value of \$22.92740/unit multiplied by the end of year present worth factor for the EOD obtained from Table 9, 0.06930, which produces a cost of \$1.59/unit.

Total LCC for Construction and Maintenance and Repair. The total LCC per unit for the DOS is the sum of the present worth costs for the initial cost of \$62.30/unit plus the 25-year maintenance cost of \$51.89/unit minus the retention value of \$1.59/unit.

Total LCC = \$62.30/unit + \$51.89/unit - \$1.59/unit = \$112.59/unit [Eq 13]

The total dollar cost would be the LCC per unit, \$112.59 multiplied by the number of units, 10 units, producing a total cost of \$1125.90.

Calculation Sheet. A typical calculation sheet is shown in Table 12.

Table 12

Calculation Sheet - Example 3

	Calculation Column	Subfactor Cost/Unit	Factor Cost/Unit	Total Cost
Initial Cost				
Initial Cost	\$79.06/unit			
PWF for BOD	x .7880			
Initial Cost/unit			\$62.30	
25-Year Maintenance Cost				
PW Total	\$54.05/unit			
LAF	x .96			
Maintenance Cost/unit			\$51.89	
Retention Value				
Initial Cost	\$22.92740/unit			
Remaining Life	x .29			
PWF for EOS	x .06930			
Retention value/unit		\$1.59/unit		
Life-Cycle Cost/unit			\$112.59	
Units			x 10 unit	
TOTAL Life-Cycle Cost				\$1125.90

Example 4: DOS Less Than 3 Years Before BOD

Perform the calculations as shown in Examples 1 through 3. The answers are lower than the actual DOS answers. The calculated values must be adjusted by multiplying by the formula:

$$(1 + DR)^{(3-A)} \qquad \text{[Eq 14]}$$

where DR = discount rate
3 = years between DOS and BOD given in the tables
A = actual years between DOS and BOD

For example, using the answer of $1038.00 in Example 1 and assuming 1 year between BOD and DOS with discount rate = 10% (0.10), the formula would be $(1.10)^{(3-1)} = (1.1)^{(2)} = 1.21$. The correct answer would be $1038.00 x 1.21 = $1255.98.

Example 5: DOS Greater Than 3 Years Before BOD

Perform the calculation as shown in Examples 1 through 3. The answers are larger than the actual DOS answers. The calculated values must be adjusted by dividing by the formula:

$$(1 + DR)^{(A-3)} \qquad \text{[Eq 15]}$$

where DR = discount rate
3 = years between DOS and BOD given in the tables
A = actual years between DOS and BOD

For example, using the answer of $1038.00 in Example 1 and assuming 5 years between BOD and DOS with d = 10% (0.10), the formula would be $(1.10)^{(5-3)} = (1.10)^{(2)} = 1.21$. The correct answer would be $1038.00 ÷ 1.21 = $857.85.

Example 6: Computer Input—BOD 3 Years After DOS

Problem Statement. This example demonstrates all steps using a system of ten flush tank water closets. An apartment building for family housing is under design at Fort Eustis, VA. The BOD is July 1992. The DOS is 3 years before BOD or July 1989. A 25-year LCC analysis using a 10 percent discount rate is required. A computer program, such as the Corps' LCCID, that requires an annual maintenance figure and high cost tasks will be used.

Installation Related Data.

Geographic Location Adjustment Factor. The LAF can be obtained from the latest EIRS bulletin or from the Area Cost Factor Newsletter on the PAX computer system as shown in Appendix D. The factors are indexed by state and then by location within the state. From Appendix D, for Virginia and Fort Eustis, the geographic LAF (or ACF Index) is 0.96.

Inflation. The cost data in Appendix B is expressed in July 1988 dollars. Since the DOS is July 1989, all cost figures must be adjusted. A telephone conversation with a District cost estimator has revealed that the costs have risen 2 percent from July 1988 to July 1989. This means that all costs need to be multiplied by a 1.02 cost adjustment factor.

Resource Rates. The labor and equipment resources in Appendix B are expressed in hours per unit measure. To obtain accurate cost figures the designer called the Fort Eustis DEH-MES branch. The July 1989 rates of $13.50/hr for a plumber and $3.00/hr for a maintenance truck were obtained.

Component Information.

Size. The designer is considering a system of ten water closets.

Initial Costs. The designer obtained a *CACES Unit Price Manual* from the cost estimator. By looking up the flush tank component, a cost of $79.06/unit was obtained. (Note: if the component is not found in the *CACES Unit Price Manual,* other books such as Means and Dodge can be used.)

Retention Value. The average life of a flush tank is 35 years, as shown for the replacement table in Appendix B. At the end of the 25-year analysis period, the water closet would still have 10 years of life remaining or 10/35 = 29 percent of its useful life. The retention value can be considered to be 29 percent of the initial cost of $79.06/unit, or $22.93/unit.

Data Entry Calculations. Four factors need to be considered when performing a present worth calculation: initial cost, annual maintenance costs, high costs, and retention value. Each factor is discussed below.

Initial Costs. The initial cost of $79.06/unit is estimated from CACES as discussed above.

25-Year Maintenance Cost. The total annual 25-year maintenance cost is composed of three parts: labor, material, and equipment. Annual labor costs unit is equal to the labor hours per units obtained from Appendix B, multiplied by the installation labor hourly rate. This would be .32389 hr/unit/yr multiplied by a labor rate of $13.50/hr, which is equal to $4.37252/unit.

$$\text{Labor} = .32389 \text{ hr/unit/yr} \times \$13.50\text{/hr} = \$4.37252\text{/unit/yr} \qquad \text{[Eq 16]}$$

Annual material costs per unit is equal to the material dollars in Washington, DC, base per units obtained from Appendix B, multiplied by the geographic LAF from Appendix D, and then multiplied by the inflation factor. This would be $.69399 DC-based dollars per units multiplied by a geographic LAF of 0.96 and a CEF of 1.02, or $.67955/unit.

$$\text{Material} = \$.69399\text{/unit/yr} \times 0.96 \times 1.02 = \$.67955\text{/unit/yr} \qquad \text{[Eq 17]}$$

Annual equipment costs per unit is equal to the equipment hours per units obtained from Appendix B, multiplied by the installation equipment hourly rate. This would be .32389 hr/units multiplied by an equipment rate of $3.00/hr, which is equal to $.97167/units.

$$\text{Equipment} = .32389 \text{ hr/unit/yr} \times \$3.00\text{/hr} = \$.97167\text{/unit/yr} \qquad \text{[Eq 18]}$$

The total annual maintenance cost per unit would be the labor cost ($4.37252/unit) plus the material cost ($.67955/unit), plus the equipment cost ($.97167/unit) or $6.02/unit

$$\text{Total: } \$4.37252\text{/unit/yr} + \$.67955\text{/unit/yr} + \$.97167\text{/unit/yr} = \$6.02\text{/unit/yr} \qquad \text{[Eq 19]}$$

The total cost figure for the uniform maintenance cost for computer entry is obtained by multiplying the total of $6.02374 by the number of units, resulting in an annual cost of $60.24.

High Cost. There are no high-cost tasks for flush tank water closets.

Calculation Sheet. A typical calculation sheet is shown in Table 13.

Example 7: Extraordinary Energy-Saving Design Initiatives—Flush Tank Water Closet

Problem Statement. This example demonstrates all steps involved in using the summary tables in Appendix A for the conventional flush tank water closet alternative. An apartment building for family housing is under design at Fort Eustis, VA. The designers are considering the use of a new-technology energy conserving, low maintenance hot water heater, in place of a conventional water heater and will

Table 13

Calculation Sheet - Example 6

ANNUAL MAINTENANCE

	Calculation Column	Subfactor Cost/Unit	Factor Cost/Unit
Initial Cost			
Initial Cost/unit	$79.06/unit		
Unit	x 10 unit		
Initial Cost			$790.60
25-Year Annual Maintenance			
Labor hours/unit	.32389 hr/unit		
Labor Rate	x $13.50/hr		
Labor cost/unit		$4.37252/unit	
Material/unit	$.69389/unit		
AF	x .96		
CEF	x 1.02		
Material cost/unit		.67946	
Equipment	.32389 hr/unit		
Equipment Rate	x $3.00/hr		
Equipment cost/unit		$.97167/unit	
Annual Maintenance/unit		$ 6.02363/unit	
Units		x 10 units	
Retention Value			
Initial Cost	$79.06/unit		
Remaining Life	x .29		
Retention value/unit	22.92740		
TOTAL Annual Maintenance		$60.24	

determine which is more cost effective on the basis of a life-cycle cost analysis. The DOS is July 1989. The analysis period is 25 years. In accordance with established criteria for energy-conservation studies, the BOD is assumed to occur on the DOS (July 1989); all costs are assumed to be incurred at the end of the year in which they are projected to be incurred; and the discount rate for the present worth calculations is assumed to be seven percent.

Installation Related Data.

Geographic Location Adjustment Factor. The geographic LAF can be obtained from the latest EIRS bulletin or from the Area Cost Factor Newsletter on the PAX computer system as shown in Appendix D. The factors are indexed by state and then by location within the state. From Appendix D, for Virginia and Fort Eustis, the geographic LAF (or ACF Index) is 0.96.

Inflation. The cost data in Appendix A is expressed in July 1988 dollars. Since the DOS is July 1939, all cost figures must be adjusted. A telephone conversation with a District cost estimator has revealed that the costs have risen 2 percent from July 1988 to July 1989. This means that all costs need to be multiplied by a 1.02 cost adjustment factor.

Resource Rates: The labor and equipment resources in Appendix B are expressed in hours per unit measure. To obtain accurate cost figures, the designer called the Fort Eustis DEH-MIS branch. The July 1989 rates of $13.50/hr for a plumber and $3.00/hr for a maintenance truck were obtained.

Component Information.

Size. The designer is considering a plumbing system with 1000 gallon capacity hot water heater.

Initial Costs. The designer obtained a *CACES Unit Price Manual* from the cost estimator. For the hot water heater component a cost figure of $15601.00/unit was obtained. (Note: if the component is not found in the *CACES Unit Price Manual*, other books such as Means and Dodge can be used.)

Retention Value. The average life of a water heater is 15 years as shown for the replacement task in Appendix B. At the end of the 25-year analysis period, the water closets would still have 10 years of life remaining or 5/15 = 33 percent of its useful life. The retention value can be considered to be 33 percent of the initial cost of $15601.00/unit or $5148.33/unit.

Present Worth Calculations. The following factors are considered in performing the present worth calculation: initial cost, maintenance costs, and retention value. Each factor is discussed below.

Initial Costs. The initial cost of $15601.00/unit is assumed to occur on the BOD/DOS in accordance with established criteria for energy conservation studies.

25-Year Maintenance Cost. The total 25-year maintenance cost is composed of three parts: labor, material, and equipment. Labor costs per unit is equal to the labor hours per units obtained from Appendix A multiplied by the installation labor hourly rate. This would be 7.64206 hr/unit multiplied by a labor rate of $13.50/hr which is equal to $103.17/unit.

$$\text{Labor} = 7.64206 \text{ hr/unit} \times \$13.50/\text{hr} = \$103.17/\text{unit} \qquad \text{[Eq 20]}$$

Material costs per unit are equal to the material dollars in Washington, DC, base per unit obtained from Appendix A multiplied by the geographic LAF from Appendix D and then multiplied by the inflation factor. This would be $5310.79080 DC-based dollars per unit multiplied by a geographic LAF of 0.96 and a CEF of 1.02, which is equal to $5200.33/unit.

Material = $5310.79080/unit x 0.96 x 1.02 = $5200.33/unit [Eq 21]

Equipment costs per unit are equal to the equipment hours per unit obtained from Appendix A multiplied by the installation equipment hourly rate. This would be 6.78933 hr/unit multiplied by an equipment rate of $3.00/hr, which is equal to $20.37/unit.

Equipment = 6.78933 hr/unit x $3.00/hr = $20.37/unit [Eq 22]

The total maintenance cost per unit would be the labor cost ($103.17/unit) plus the material cost ($5200.33/unit) plus the equipment cost ($20.37/unit).

Total = $103.17/unit + $5200.33/unit + $20.37/unit = $5323.87/unit [Eq 23]

This total has already been discounted to the date of study since all figures on the left side of the table in the Appendix are expressed in terms of the DOS.

Retention Value. The DOS present worth for the retention value would be the expected retention value of $5148.33/unit multiplied by the end of year present worth factor for the EOD of 0.1842 obtained from Table 8 which produces a cost of $948.32/unit.

Total Life-Cycle Cost for Construction and Maintenance and Repair. The total LCC per unit for the DOS is the sum of the present worth costs for the initial cost of $15601.00/unit plus the 25-year maintenance cost of $5323.86/unit minus the retention value of $948.32/unit.

Total LCC = $15601.00/unit + $5323.86/unit - $948.32/unit = $19976.54/unit [Eq 24]

The total dollar cost would be the LCC of 19976.54.

Calculation Sheet. A typical calculation sheet is shown in Table 14.

Table 14

Calculation Sheet - Example 7

	Calculation Column	Subfactor Cost/Unit	Factor Cost/Unit	Total Cost
Initial Cost				
Initial Cost			$15601.00/unit	
25 Year Maintenance Cost				
PW - Labor	7.64206 hr/unit			
Labor Rate	x $13.50/hr			
Labor cost/unit		$103.17/unit		
PW - Material	$5310.79080/unit			
LAF	x .96			
CEF	x 1.02			
Material cost/unit		$5200.33/unit		
PW - Equipment	6.78933 hr/unit			
Equipment Rate	x $3.00/hr			
Equipment cost/unit		$20.37/unit		
Maintenance cost/unit			$5323.86/unit	
Retention Value				
Initial Cost	$15601.00/unit			
Remaining Life	x .33			
PWF for EOS	x .1842			
Retention value/unit			- 948.32/unit	
TOTAL Life-Cycle Cost				$19976.54

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LIST OF ACRONYMS

ACE	Assistant Chief of Engineers
AMS	Army Management System
APC	Account Processing Code
AR	Army Regulation
ARR	Annual Requirements Report
ASTM	American Society for Testing and Materials
BLAST	Building Loads Analysis and System Thermodynamics
BMAR	Backlog of Maintenance and Repair
CA	Commercial Activities
CACES	Computer-Assisted Cost Estimating System
CONUS	Continental United States
DA	Department of the Army
DEH	Directorate of Engineering and Housing
DOD	Department of Defense
EA	Economic Analysis
EPS	Engineered Performance Standards
HQ-IFS	Headquarters - Integrated Facilities System
HQDA	Headquarters, Department of the Army
HVAC	Heating, Ventilation, and Air-Conditioning
IFS	Integrated Facilities System
IJO	Individual Job Order
LCC	Life-Cycle Cost
LCCID	Life-Cycle Cost in Design
M&R	Maintenance and Repair
MACOM	Major Command

MCA	Military Construction, Army
MRPM	Maintenance Resource Prediction Model
OCE	Office of the Chief of Engineers
PAVER	Pavement Maintenance Management System
PC	Personal Computer
PM	Preventive Maintenance
R&D	Research and Development
RAM	Random Access Memory
RMF	Recurring Maintenance Factor
RPI	Real Property Inventory
RPLANS	Real Property Planning System
RPMS	Real Property Management System
SO	Service Order
STANFINS	Standard Army Financial System
TB	Technical Bulletin
URR	Unconstrained Requirements Report
USACE	U.S. Army Corps of Engineers
USACERL	U.S. Army Construction Engineering Research Laboratory
USAEHSC	U.S. Army Engineering and Housing Support Center

APPENDIX A:

LIFE-CYCLE COST ANALYSIS (7 PERCENT)

COMPONENT DESCRIPTION	um	PRESENT WORTH OF ALL 25 YEAR MAINTENANCE AND REPAIR COSTS (d= 7%) By Resources labor	material	equipment	Washington D.C. Total	ANNUAL MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS Annual Maintenance and Repair labor	material	equipment	Replacement and High Costs Tasks yr	labor	material	equipment
PLUMBING												
SANITARY												
FIXTURES												
TANK-LESS WATER CLOSET	CT	3.29053	12.01873	3.29053	81.75	0.28236	1.03133	0.28236	35	2.02280	188.09700	1.01140
FLUSH-TANK WATER CLOSET	CT	4.05835	9.18744	4.05835	95.18	0.34825	0.78838	0.34825	35	4.11190	79.06540	2.05595
URINAL	CT	5.01183	19.12038	5.01183	125.32	0.43007	1.64073	0.43007	35	2.13330	167.48000	1.06665
LAVATORY, IRON, ENAMEL	CT	4.41775	30.76071	4.41775	124.37	0.37909	2.63959	0.37909	40	1.99550	138.44660	0.99775
LAVATORY, VITREOUS CHINA	CT	4.41775	30.76071	4.41775	124.37	0.37909	2.63959	0.37909	35	1.99680	142.18840	0.99840
LAVATORY, ENAMELED STEEL	CT	4.41875	30.76071	4.41875	124.39	0.37917	2.63959	0.37917	35	1.99680	61.79800	0.99840
BATHTUB, CAST IRON ENAMEL	CT	6.96328	75.40727	6.96328	222.96	0.59752	6.47073	0.59752	40	13.00000	341.29880	6.50000
BATHTUB, ENAMELED STEEL	CT	9.21535	77.56639	9.21535	272.84	0.79077	6.65600	0.79077	35	3.34100	174.12620	1.67050
SHOWER, TERRAZO	CT	6.56251	43.43485	6.56251	182.49	0.56313	3.72716	0.56313	30	98.91700	243.69400	49.45850
SHOWER, ENAMELED STEEL	CT	6.56251	43.43485	6.56251	182.49	0.56313	3.72716	0.56313	35	3.36700	262.88000	1.68350
SHOWER, PLASTIC	CT	6.81162	57.80688	6.37660	200.75	0.50985	2.61029	0.50985	20	3.36700	105.98940	1.68350
SHOWER, ALUMINUM	CT	7.04863	76.38948	6.73853	224.76	0.55163	3.71510	0.55163	25	3.36700	179.67000	1.68350
SINK, IRON ENAMEL	CT	6.49703	35.57521	6.49703	173.25	0.55751	3.05272	0.55751	35	3.06800	147.08560	1.53400
SINK, ENAMELED STEEL	CT	6.50167	35.57521	6.50167	173.35	0.55791	3.05272	0.55791	35	3.06800	71.02000	1.53400
SINK, STAINLESS STEEL	CT	6.50887	40.45142	6.50887	178.37	0.55853	3.47115	0.55853	40	3.06800	210.61140	1.53400
SINK, PLASTIC	CT	6.96546	55.05953	6.45194	201.01	0.50958	2.76302	0.50958	15	2.83400	63.08060	1.41700
DRINKING FOUNTAIN	CT	20.41855	401.34610	19.89029	832.32	1.66146	1.78123	1.66146	10	1.[illegible]7800	496.39800	0.68900
SPIGOT	CT	1.80668	6.35135	1.80668	44.63	0.13793	0.18237	0.13793	10	0.26000	5.51200	0.26000
BATHTUB, PLASTIC	CT	9.47124	173.63175	7.79164	368.95	0.52448	5.06306	0.52448	20	13.00000	443.61000	6.50000
LAVATORY, PLASTIC	CT	4.47448	41.57111	4.21649	135.56	0.33968	1.85146	0.33968	20	1.99680	77.38000	0.99840
EMERGENCY SHOWER STATION	CT	1.16277	27.21085	0.92331	51.08	0.05868	0.07310	0.05868	25	2.60000	143.10000	1.30000
EMERGENCY EYE WASH	CT	1.16277	21.15804	0.92331	45.03	0.05868	0.07310	0.05868	25	2.60000	110.24000	1.30000
SHOWER, CMU	CT	31.50174	85.20002	18.72166	711.83	0.50985	2.61029	0.50985	20	98.51700	212.00000	49.45850
SHOWER GLAZED CMU	CT	24.64174	87.22597	15.53149	580.23	0.55101	3.71510	0.55101	25	98.51700	238.50000	49.45850
SHOWER, CERAMIC TILE	CT	6.56251	43.43485	6.56251	182.49	0.56313	3.72716	0.56313	30	98.91700	190.80000	49.45850
WASTE AND VENT SYSTEMS												
PIPE & FITTINGS,C.I.	TF	1.97161	9.69447	1.97161	51.47	0.16918	0.83189	0.16918	40	323.47900	2162.40000	161.73950
FLOOR DRAIN, W/O BUCKET	CT	5.48707	0.14791	5.48707	116.42	0.47085	0.01269	0.47085	40	1.53400	92.94080	1.53400
FLOOR DRAIN WITH BUCKET	CT	7.99769	0.07395	7.99769	169.55	0.68629	0.00635	0.68629	40	3.06800	183.38000	3.06800
PIPE AND FITTINGS, PVC	TF	46.51117	1489.70463	24.24139	2404.01	0.16918	0.83189	0.16918	25	241.[illegible]0000	8034.80000	120.90000
COLD WATER SYSTEMS												
PIPE/FITTINGS, STEEL/IRON	TF	6.88830	12.36810	3.44415	147.31	0.59109	1.06131	0.29554	75	1074.4500	1929.20000	537.22500
PIPE/FITTINGS, COPPER	TF	11.80085	207.95561	5.97119	439.36	0.13523	0.25237	0.07369	25	55.51000	1113.00000	27.75500
VALVE, NON-DRAIN,<1 1/2"	CT	0.24692	3.07490	0.24692	8.31	0.01542	0.01942	0.01542	20	0.26000	11.02400	0.26000
VALVE, NON-DRAIN, 2"- 3"	CT	0.32820	20.08329	0.32820	27.04	0.01548	0.03884	0.01548	20	0.57200	75.97020	0.57200
VALVE, NON-DRAIN, 4"- 6"	CT	8.22181	40.02051	7.71793	212.63	0.61904	0.65297	0.61904	20	3.90000	125.42980	1.95000
VALVE, DRAIN	CT	1.63463	12.09692	1.63463	46.73	0.12903	0.58959	0.12903	20	0.50700	20.22480	0.50700
EXPANSION CHAMBER	CT	1.02590	159.85036	1.02590	181.59	0.00422	0.00000	0.00422	10	1.27400	208.49140	1.27400
WATER METER	CT	0.68557	17.27035	0.68557	31.80	0.04629	0.11513	0.04629	25	0.79300	86.47480	0.79300
INSULATION, PIPE	TF	11.97764	246.55765	11.97764	500.36	0.04826	0.06054	0.04826	15	31.49900	678.40000	31.49900
CIRC. PUMP - 1/8 HP.	CT	1.82973	58.67552	1.69033	97.00	0.13308	0.33421	0.13308	20	1.07900	212.00000	0.53950
CIRC. PUMP - 1/6 HP.	CT	3.12056	103.14663	2.88205	168.51	0.22684	0.62472	0.22684	20	1.84600	371.00000	0.92300
CIRC. PUMP - 1/2 HP.	CT	4.16146	38.14218	3.79027	125.14	0.29339	0.68758	0.29339	20	2.87300	116.60000	1.43650
PIPE/FITTINGS, PVC	TF	0.32781	1.75961	0.27393	8.53	0.02813	0.15099	0.02351	30	41.70530	669.12500	20.85265
HOSE BIBB	CT	1.35477	5.68079	1.35477	34.39	0.09915	0.12483	0.09915	10	0.26000	5.51200	0.26000
CIRC. PUMP > 1 HP	CT	4.16146	41.28259	3.79027	128.28	0.29339	0.95706	0.29339	20	2.87300	116.60000	1.43650
HOT WATER SYSTEMS												
PIPE/FITTINGS, STEEL/IRON	TF	6.94816	12.39934	3.50401	148.61	0.59622	1.06399	0.30068	75	1074.4500	1929.20000	537.22500
PIPE/FITTINGS, COPPER	TF	13.86030	212.18524	6.96845	483.83	0.31195	0.61532	0.15926	25	55.51000	1113.00000	27.75500
VALVE, NON-DRAIN,<1-1/2"	CT	0.64474	9.01287	0.64474	22.67	0.03822	0.04812	0.03822	10	0.26000	11.02400	0.26000
VALVE, NON-DRAIN, 2"- 3"	CT	0.88395	59.36790	0.88395	78.10	0.03822	0.09624	0.03822	10	0.57200	75.97020	0.57200
VALVE, NON-DRAIN, 4"- 6"	CT	9.88237	103.43703	8.38731	308.06	0.59143	0.62384	0.59143	10	3.90000	125.42980	1.95000
VALVE, DRAIN	CT	1.77892	29.67745	1.77892	67.37	0.11929	1.21603	0.11929	10	0.50700	20.22480	0.50700
EXPANSION CHAMBER	CT	0.47392	66.00838	0.47392	76.05	0.00606	0.00000	0.00606	17	1.27400	208.49140	1.27400
INSULATION, PIPE	TF	12.76183	247.54138	12.76183	517.96	0.11555	0.14495	0.11555	15	31.49900	678.40000	31.49900

See NOTES on the last page of this table for Explanation of Column Headings

COMPONENT DESCRIPTION	um	PRESENT WORTH OF ALL 25 YEAR MAINTENANCE AND REPAIR COSTS (d= 7%) By Resources labor	material	equipment	Washington D.C. Total	ANNUAL MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS Annual Maintenance and Repair labor	material	equipment	Replacement and High Costs Tasks yr	labor	material	equipment
CIRC. PUMP - 1/12 HP.	CT	3.94175	170.41029	3.52811	252.61	0.26725	0.67532	0.26725	10	1.07900	212.00000	0.53950
CIRC. PUMP - 1/6 HP.	CT	4.55109	292.68943	3.84343	386.86	0.26908	0.70740	0.26908	10	1.84600	371.00000	0.92300
CIRC. PUMP - 1/2 HP.	CT	6.85924	428.56249	5.75788	570.39	0.39958	1.06912	0.39958	10	2.87300	542.72000	1.43650
STEAM CONVERTER, DOM. H.W.	CT	16.76409	216.38981	8.90791	546.48	1.27538	1.17568	0.68282	20	7.35800	784.40000	3.67900
H.W. HTR.,GAS/OIL,30 GAL.	CT	35.49316	111.34017	35.08252	862.13	2.97521	0.00000	2.97521	10	1.07120	145.22000	0.53560
H.W. HTR.,GAS/OIL,80 GAL.	CT	40.90120	469.85535	39.09683	1330.78	3.20008	0.89833	3.20008	12	5.62900	716.56000	2.81450
H.W. HTR.,GAS/OIL,1000 GPH	CT	190.55716	1646.27808	95.27858	5379.29	15.33194	0.00000	7.66597	20	45.99400	6371.04520	22.99700
H.W. HTR., GAS/OIL 8-120 G	CT	40.90120	643.14468	39.09683	1504.07	3.20008	0.89833	3.20008	12	5.62900	986.86000	2.81450
H.W. HTR. ELEC. 120 GAL.	CT	7.64206	1104.41400	6.78933	1263.62	0.50942	0.00000	0.50942	15	4.70600	3047.50000	2.35300
H.W. HEATER ELEC. 300 GAL.	CT	7.64206	2045.56680	6.78933	2204.77	0.50942	0.00000	0.50942	15	4.70600	5644.50000	2.35300
H.W. HEATER ELEC. 1000 GAL	CT	7.64206	5310.79080	6.78933	5470.00	0.50942	0.00000	0.50942	15	4.70600	14654.50000	2.35300
H.W. HEATER ELEC. 2000 GAL	CT	7.64206	6847.36680	6.78933	7006.57	0.50942	0.00000	0.50942	15	4.70600	18894.50000	2.35300
H.W. HTR.,ELEC.,52 GAL.	CT	7.36928	119.60362	5.86077	270.93	0.37347	0.00000	0.37347	12	4.70600	186.56000	2.35300
STORAGE TANK, DHW	CT	20.68248	29.36465	20.68248	467.63	1.77477	2.51979	1.77477	50	3.59395	346.62000	1.79698
PIPE/FITTINGS, PVC	TF	8.12633	125.27415	4.22357	284.98	0.03812	0.17345	0.03282	25	41.70530	669.12500	20.85265
CIRC. PUMP > 1 HP	CT	4.16146	312.44755	3.79027	399.44	0.29339	0.95706	0.29339	20	2.87300	1166.00000	1.43650
RAINWATER DRAINAGE												
FIXTURES												
DRAIN; ROOF, SCUPPER, AREA	CT	5.90817	4.44686	5.90817	129.64	0.50698	0.38159	0.50698	40	1.31300	175.44060	1.31300
DRAINAGE SYSTEMS												
DISTRIBUTION;GUTTERS,PIPE	TF	113.92656	317.10792	113.92656	2731.21	5.18621	1.59200	5.18621	20	206.99900	1155.40000	206.99900
PUMPS												
SUMP PUMP	CT	4.16146	113.46578	3.79027	200.46	0.29339	0.68758	0.29339	20	2.87300	408.10000	1.43650
SPECIAL PLUMBING												
COMPRESSED AIR SYSTEMS												
SIMPLEX AIR COMPR., 1 HP.	CT	51.81112	1175.19147	34.32954	2217.13	4.38778	4.36483	2.91676	25	3.67900	6103.82980	1.83950
VACUUM PUMP	CT	12.93575	2254.51853	10.69315	2521.45	0.72515	18.97595	0.72515	10	5.85000	2652.12000	2.92500
GAS COMPRESSOR 7 1/2 HP	CT	51.85183	717.07113	34.34989	1759.81	4.38778	8.75316	2.91676	25	3.90000	3339.11660	1.95000
GAS COMPRESSOR > 15 HP	CT	51.97156	1173.36680	34.40976	2218.45	4.38778	16.06670	2.91676	25	4.55000	5353.59360	2.27500
COMPRESSED AIR DRYER	CT	7.03316	947.59548	7.03316	1107.11	0.54288	25.93478	0.54288	15	1.95000	1780.80000	1.95000
HOSE, COMPRESSED AIR	CT	0.94831	47.46810	0.94831	67.56	0.00000	0.00000	0.00000	5	0.46800	23.42600	0.46800
PIPE/FITTINGS COMPR. AIR	TF	38.43797	78.65404	19.27300	831.83	3.29838	6.74933	1.65382	75	1074.4500	2204.80000	537.22500
INDUSTRIAL GASEOUS SYS.												
SIMPLEX GAS COMPR., 1 HP.	CT	51.81112	302.45018	34.32954	1344.39	4.38778	4.36483	2.91676	25	3.67900	1365.82060	1.83950
HOSE, INDUSTRIAL GAS	CT	0.94831	47.46810	0.94831	67.56	0.00000	0.00000	0.00000	5	0.46800	23.42600	0.46800
PIPE/FITTINGS,INDUST. GAS	TF	27.86216	56.95219	13.98510	602.94	2.39086	4.88709	1.20007	75	1074.4500	2204.80000	537.22500
SPECIAL GAS SYSTEM												
PIPE/FITTINGS, ANETHESIA	TF	105.88478	212.18524	52.98069	2286.59	0.31195	0.61532	0.15926	25	555.10000	1113.00000	277.55000
PIPE/FITTINGS, OXYGEN	TF	105.88478	212.18524	52.98069	2286.59	0.31195	0.61532	0.15926	25	555.10000	1113.00000	277.55000
SPECIAL PLUMBING FIXT.												
KITCHEN SYSTEMS												
DISHWASHER	CT	17.34844	402.52972	15.04604	762.78	1.09354	4.32155	1.09354	10	6.00600	459.32980	3.00300
WASTE DISPOSAL, RESIDENT.	CT	10.60041	123.42770	10.60041	348.05	0.78742	0.00000	0.78742	8	1.27400	110.42000	1.27400
WATER SOFTENER	CT	81.66128	4865.06896	80.71904	6592.46	6.84568	394.72863	6.84568	15	5.20000	731.40000	2.60000
SPRINKLER SYSTEM												
SPRINKLER HEAD	CT	0.56710	2.15952	0.56710	14.18	0.04146	0.09247	0.04146	20	0.32500	4.18700	0.32500

See NOTES on the last page of this table for Explanation of Column Headings

Notes

1. The resources listed in this table are as of the Date of Study (DOS) and have been calculated using a present worth discount factor (d) of 7 percent. The Date of Study (DOS) is the Beneficial Occupancy Date (BOD). All tasks are assumed to occur at the end of the year. All resources have been assumed to be constant with no differential escalation from year to year.

2. Component Description - This column contains an indented list of systems, subsystems, components, and high cost task descriptions.

3. Unit of Measure (UM) - This column contains a two-character code to indicate the measurement unit for the component. Units used in this column are as follows:

CT	Count
LF	Linear Foot
SF	Square Foot
TF	Thousands of Linear Feet

4. Labor - Labor resources can be used in one of two ways: (1) labor hours per unit of measure, or (2) dollars per unit of measure assuming a $1.00/hr labor rate.

5. Materials - Material resources are expressed in dollars per unit of measure in July 1988 dollars for the Washington, DC, area.

6. Equipment - Equipment resources can be used in one of two ways: (1) equipment hours per unit of measure, or (2) dollars per unit of measure assuming a $1.00/hr equipment rate.

7. Washington, DC, Total - The dollars per unit of measure figures were calculated by applying the Military District of Washington labor and equipment rates to the labor and equipment resources, then adding the labor, material, and equipment costs together to form one total cost figure.

8. Year (YR) - This column contains the average age of the component when the high cost task or replacement task would be performed.

9. Engineered Performance Standards (EPS) - Most labor and equipment resource data is based on the DOD series of Technical Bulletins as discussed in the body of the report.

APPENDIX B:

LIFE-CYCLE COST ANALYSIS (10 PERCENT)

COMPONENT DESCRIPTION	um	PRESENT WORTH OF ALL 25 YEAR MAINTENANCE AND REPAIR COSTS (d=10%)				ANNUAL MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS						
		By Resources			Washington	Annual Maintenance and Repair			Replacement and High Costs Tasks			
		labor	material	equipment	D.C. Total	labor	material	equipment	yr	labor	material	equipment
PLUMBING												
SANITARY												
FIXTURES												
TANK-LESS WATER CLOSET	CT	1.89994	6.68070	1.89994	46.94	0.26563	0.93402	0.26563	35	2.02280	188.09700	1.01140
FLUSH-TANK WATER CLOSET	CT	2.31668	4.96386	2.31668	54.05	0.32389	0.69399	0.32389	35	4.11190	79.06540	2.05595
URINAL	CT	2.89694	10.99923	2.89694	72.38	0.40502	1.53640	0.40502	35	2.13330	167.48000	1.06665
LAVATORY, IRON, ENAMEL	CT	2.63599	17.12850	2.63599	72.99	0.36854	2.39472	0.36854	40	1.99[illegible]50	138.44660	0.99775
LAVATORY, VITREOUS CHINA	CT	2.63599	17.12850	2.63599	72.99	0.36854	2.39472	0.36854	35	1.99680	142.18840	0.99840
LAVATORY, ENAMELED STEEL	CT	2.63654	17.12850	2.63654	73.00	0.36861	2.39472	0.36861	35	1.99680	61.79800	0.99840
BATHTUB, CAST IRON ENAMEL	CT	4.06822	42.96166	4.06822	129.17	0.56877	6.00644	0.56877	40	13.00000	341.29880	6.50000
BATHTUB, ENAMELED STEEL	CT	[illegible].47173	44.30948	5.47173	160.26	0.76500	6.19488	0.76500	35	3.34100	174.12620	1.67050
SHOWER, TERRAZO	CT	3.90504	24.15328	3.90504	106.90	0.54596	3.37685	0.54596	30	98.91700	243.69400	49.45850
SHOWER, ENAMELED STEEL	CT	3.90504	24.15328	3.90504	106.90	0.54596	3.37685	0.54596	35	3.36700	262.88000	1.68350
SHOWER, PLASTIC	CT	4.01848	30.66697	3.82134	115.19	0.50670	2.55230	0.50670	20	3.36700	105.98940	1.68350
SHOWER, ALUMINUM	CT	4.09845	37.15981	3.97606	123.61	0.53878	3.36910	0.53878	25	3.36700	179.67000	1.68350
SINK, IRON ENAMEL	CT	3.83929	19.82560	3.83929	101.18	0.53677	2.77180	0.53677	35	3.06800	147.08560	1.53400
SINK, ENAMELED STEEL	CT	3.84207	19.82560	3.84207	101.24	0.53716	2.77180	0.53716	35	3.06800	71.02000	1.53400
SINK, STAINLESS STEEL	CT	3.84646	22.50252	3.84646	104.01	0.53777	3.14606	0.53777	40	3.06800	210.61140	1.53400
SINK, PLASTIC	CT	4.07780	29.74389	3.81055	115.30	0.49539	2.49516	0.49539	15	2.83400	63.08060	1.41700
DRINKING FOUNTAIN	CT	12.47709	221.67648	12.18709	485.16	1.66332	1.78153	1.66332	10	1.37800	496.39800	0.68900
SPIGOT	CT	1.10283	3.63352	1.10283	27.00	0.13889	0.18364	0.13889	10	0.26000	5.51200	0.26000
BATHTUB, PLASTIC	CT	5.21063	87.48038	4.44948	195.46	0.51566	4.96794	0.51566	20	13.00000	443.61000	6.50000
LAVATORY, PLASTIC	CT	2.66171	22.02786	2.54480	78.06	0.33944	1.81286	0.33944	20	1.99680	77.38000	0.99840
EMERGENCY SHOWER STATION	CT	0.58532	10.89683	0.49081	23.00	0.05541	0.06899	0.05541	25	2.60000	143.10000	1.30000
EMERGENCY EYE WASH	CT	0.58532	8.50791	0.49081	20.61	0.05541	0.06899	0.05541	25	2.60000	110.24000	1.30000
SHOWER, CMU	CT	15.20738	43.08081	9.41579	346.79	0.50670	2.55230	0.50670	20	98.91700	212.00000	49.45850
SHOWER GLAZED CMU	CT	11.04055	41.43675	7.44492	263.88	0.53817	3.36910	0.53817	25	98.91700	238.50000	49.45850
SHOWER, CERAMIC TILE	CT	3.90504	24.15328	3.90504	106.90	0.54596	3.37685	0.54596	30	98.91700	190.80000	49.45850
WASTE AND VENT SYSTEMS												
PIPE & FITTINGS,C.I.	TF	0.95364	4.69226	0.95364	24.90	0.13333	0.65602	0.13333	40	323.47900	2162.40000	161.73950
FLOOR DRAIN, W/O BUCKET	CT	3.22019	0.06703	3.22019	68.30	0.45021	0.00937	0.45021	40	1.53400	92.94080	1.53400
FLOOR DRAIN WITH BUCKET	CT	4.60537	0.03351	4.60537	97.62	0.64387	0.00469	0.64387	40	3.06800	183.38000	3.06800
PIPE AND FITTINGS, PVC	TF	18.53250	588.82222	9.74307	953.40	0.13333	0.65602	0.13333	25	241.80000	8034.80000	120.90000
COLD WATER SYSTEMS												
PIPE/FITTINGS, STEEL/IRON	TF	3.55750	6.38758	1.77875	76.08	0.49737	0.89304	0.24869	75	1074.4500	1929.20000	537.22500
PIPE/FITTINGS, COPPER	TF	4.76330	82.25412	2.42050	175.69	0.10174	0.18721	0.05630	25	55.51000	1113.00000	27.75500
VALVE, NON-DRAIN,<1 1/2"	CT	0.13787	1.42616	0.13787	4.35	0.01502	0.01891	0.01502	20	0.26000	11.02400	0.26000
VALVE, NON-DRAIN, 2"- 3"	CT	0.17480	9.16661	0.17480	12.87	0.01507	0.03782	0.01507	20	0.57200	75.97020	0.57200
VALVE, NON-DRAIN, 4"- 6"	CT	4.91087	19.38614	4.68252	122.72	0.62274	0.65687	0.62274	20	3.90000	125.42980	1.95000
VALVE, DRAIN	CT	0.96777	6.43637	0.96777	26.94	0.12700	0.56875	0.12700	20	0.50700	20.22480	0.50700
EXPANSION CHAMBER	CT	0.56550	87.75403	0.56550	99.74	0.00409	0.00000	0.00409	10	1.27400	208.49140	1.27400
WATER METER	CT	0.35444	7.02481	0.35444	14.54	0.04149	0.10319	0.04149	25	0.79300	86.47480	0.79300
INSULATION, PIPE	TF	6.27293	128.36299	6.27293	261.29	0.04645	0.05827	0.04645	15	31.49900	678.40000	31.49900
CIRC. PUMP - 1/8 HP.	CT	1.07788	27.21502	1.01470	49.85	0.13303	0.33412	0.13303	20	1.07900	212.00000	0.53950
CIRC. PUMP - 1/6 HP.	CT	1.83216	47.89116	1.72408	86.37	0.22593	0.62174	0.22593	20	1.84600	371.00000	0.92300
CIRC. PUMP - 1/2 HP.	CT	2.41453	18.49877	2.24631	69.12	0.29054	0.67736	0.29054	20	2.87300	116.60000	1.43650
PIPE/FITTINGS, PVC	TF	0.16964	0.79935	0.14522	4.32	0.02372	0.11176	0.02030	30	41.70530	669.12500	20.85265
HOSE BIBB	CT	0.81225	3.20488	0.81225	20.42	0.09826	0.12371	0.09826	10	0.26000	5.51200	0.26000
CIRC. PUMP > 1 HP	CT	2.41453	20.43775	2.24631	71.06	0.29054	0.94845	0.29054	20	2.87300	116.60000	1.43650
HOT WATER SYSTEMS												
PIPE/FITTINGS, STEEL/IRON	TF	3.58113	6.39991	1.80238	76.59	0.50068	0.89477	0.25199	75	1074.4500	1929.20000	537.22500
PIPE/FITTINGS, COPPER	TF	5.91566	84.61960	2.97890	200.57	0.26285	0.51792	0.13437	25	55.51000	1113.00000	27.75500
VALVE, NON-DRAIN,<1-1/2"	CT	0.37485	4.97417	0.37485	12.92	0.03711	0.04672	0.03711	10	0.26000	11.02400	0.26000
VALVE, NON-DRAIN, 2"- 3"	CT	0.50617	32.64419	0.50617	43.37	0.03711	0.09344	0.03711	10	0.57200	75.97020	0.57200
VALVE, NON-DRAIN, 4"- 6"	CT	5.90335	57.28883	5.08259	179.75	0.59584	0.62850	0.59584	10	3.90000	125.42980	1.95000
VALVE, DRAIN	CT	1.05470	17.01963	1.05470	39.37	0.11762	1.18936	0.11762	10	0.50700	20.22480	0.50700
EXPANSION CHAMBER	CT	0.24068	32.50381	0.24068	37.60	0.00588	0.00000	0.00588	17	1.27400	208.49140	1.27400
INSULATION, PIPE	TF	6.75208	128.96405	6.75208	272.04	0.11344	0.14230	0.11344	15	31.49900	678.40000	31.49900

See NOTES on the last page of this table for Explanation of Column Headings

EPS BASED MAINTENANCE AND REPAIR COST DATA FOR USE IN LIFE CYCLE COST ANALYSIS ($ PER UNIT MEASURE)

COMPONENT DESCRIPTION		PRESENT WORTH OF ALL 25 YEAR MAINTENANCE AND REPAIR COSTS (d=10%)				ANNUAL MAINTENANCE AND REPAIR PLUS HIGH COST REPAIR AND REPLACEMENT COSTS						
		By Resources			Washington	Annual Maintenance and Repair			Replacement and High Costs Tasks			
	um	labor	material	equipment	D.C. Total	labor	material	equipment	yr	labor	material	equipment
CIRC. PUMP - 1/12 HP.	CT	2.36346	94.05520	2.13638	143.41	0.26694	0.67450	0.26694	10	1.07900	212.00000	0.53950
CIRC. PUMP - 1/6 HP.	CT	2.69897	161.20108	2.31048	217.15	0.26871	0.70564	0.26871	10	1.84600	371.00000	0.92300
CIRC. PUMP - 1/2 HP.	CT	4.06351	236.05731	3.45888	320.23	0.39905	1.06625	0.39905	10	2.87300	542.72000	1.43650
STEAM CONVERTER, DOM. H.W.	CT	9.87830	100.15379	5.26384	294.71	1.26062	1.16049	0.67570	20	7.35800	784.40000	3.67900
H.W. HTR.,GAS/OIL,30 GAL.	CT	21.84588	61.12310	21.62045	523.32	2.99122	0.00000	2.99122	10	1.07120	145.22000	0.53560
H.W. HTR.,GAS/OIL,80 GAL.	CT	24.85300	243.46088	23.92112	767.11	3.21411	0.86792	3.21411	12	5.62900	716.56000	2.81450
H.W. HTR.,GAS/OIL,1000 GPH	CT	115.46247	746.04939	57.73123	3007.96	15.38973	0.00000	7.69486	20	45.99400	6371.04520	22.99700
H.W. HTR., GAS/OIL 8-120 G	CT	24.85300	332.95721	23.92112	856.61	3.21411	0.86792	3.21411	12	5.62900	986.86000	2.81450
H.W. HTR. ELEC. 120 GAL.	CT	4.29740	574.75850	3.85362	664.40	0.47673	0.00000	0.47673	15	4.70600	3047.50000	2.35300
H.W. HEATER ELEC. 300 GAL.	CT	4.29740	1064.55270	3.85362	1154.19	0.47673	0.00000	0.47673	15	4.70600	5644.50000	2.35300
H.W. HEATER ELEC. 1000 GAL	CT	4.29740	2763.83870	3.85362	2853.48	0.47673	0.00000	0.47673	15	4.70600	14654.50000	2.35300
H.W. HEATER ELEC. 2000 GAL	CT	4.29740	3563.50270	3.85362	3653.14	0.47673	0.00000	0.47673	15	4.70600	18894.50000	2.35300
H.W. HTR. ELEC. 52 GAL.	CT	4.14308	61.77002	3.36400	147.07	0.36140	0.00000	0.36140	12	4.70600	186.56000	2.35300
STORAGE TANK, DHW	CT	12.58494	17.86789	12.58494	284.54	1.75949	2.49810	1.75949	50	3.59395	346.62000	1.79698
PIPE/FITTINGS, PVC	TF	3.26875	49.61558	1.72322	113.93	0.03310	0.13564	0.02897	25	41.70530	669.12500	20.85265
CIRC. PUMP > 1 HP	CT	2.41453	143.32249	2.24631	193.95	0.29054	0.94845	0.29054	20	2.87300	1166.00000	1.43650
RAINWATER DRAINAGE												
FIXTURES												
DRAIN; ROOF, SCUPPER, AREA	CT	3.62637	2.72943	3.62637	79.57	0.50700	0.38160	0.50700	40	1.31300	175.44060	1.31300
DRAINAGE SYSTEMS												
DISTRIBUTION;GUTTERS,PIPE	TF	61.55587	146.75226	61.55587	1451.12	5.21716	1.60150	5.21716	20	206.99900	1155.40000	206.99900
PUMPS												
SUMP PUMP	CT	2.41453	52.63342	2.24631	103.26	0.29054	0.67736	0.29054	20	2.87300	408.10000	1.43650
SPECIAL PLUMBING												
COMPRESSED AIR SYSTEMS												
SIMPLEX AIR COMPR., 1 HP.	CT	30.91580	474.23693	20.65809	1096.52	4.28492	4.26258	2.86950	25	3.67900	6103.82980	1.83950
VACUUM PUMP	CT	7.57741	1250.32107	6.34628	1406.95	0.71514	18.74056	0.71514	10	5.85000	2652.12000	2.92500
GAS COMPRESSOR 7 1/2 HP	CT	30.93186	303.89248	20.66612	926.49	4.28492	8.54776	2.86950	25	3.90000	3339.11660	1.95000
GAS COMPRESSOR > 15 HP	CT	30.97912	501.12719	20.68975	1124.65	4.28492	15.64759	2.86950	25	4.55000	5353.59360	2.27500
COMPRESSED AIR DRYER	CT	4.12649	501.21496	4.12649	594.80	0.52550	23.11832	0.52550	15	1.95000	1780.80000	1.95000
HOSE, COMPRESSED AIR	CT	0.54826	27.44356	0.54826	39.06	0.00000	0.00000	0.00000	5	0.46800	23.42600	0.46800
PIPE/FITTINGS COMPR. AIR	TF	23.04715	47.15847	11.55645	498.76	3.22221	6.59319	1.61570	75	1074.4500	2204.80000	537.22500
INDUSTRIAL GASEOUS SYS.												
SIMPLEX GAS COMPR., 1 HP.	CT	30.91580	129.78366	20.65809	752.06	4.28492	4.26258	2.86950	25	3.67900	1365.82060	1.83950
HOSE, INDUSTRIAL GAS	CT	0.54826	27.44356	0.54826	39.06	0.00000	0.00000	0.00000	5	0.46800	23.42600	0.46800
PIPE/FITTINGS,INDUST. GAS	TF	16.45648	33.63422	8.26111	356.12	2.30077	4.70238	1.15498	75	1074.4500	2204.80000	537.22500
SPECIAL GAS SYSTEM												
PIPE/FITTINGS, ANESTHESIA	TF	42.23585	84.61960	21.13900	912.09	0.26285	0.51792	0.13437	25	555.10000	1113.00000	277.55000
PIPE/FITTINGS, OXYGEN	TF	42.23585	84.61960	21.13900	912.09	0.26285	0.51792	0.13437	25	555.10000	1113.00000	277.55000
SPECIAL PLUMBING FIXT.												
KITCHEN SYSTEMS												
DISHWASHER	CT	10.27957	223.96560	9.01560	437.74	1.08375	4.28287	1.08375	10	6.00600	459.32980	3.00300
WASTE DISPOSAL, RESIDENT.	CT	6.47941	68.36115	6.47941	205.66	0.79561	0.00000	0.79561	8	1.27400	110.42020	1.27400
WATER SOFTENER	CT	50.16414	2974.98328	49.67378	4036.39	6.87630	396.64475	6.87630	15	5.20000	731.40000	2.60000
SPRINKLER SYSTEM												
SPRINKLER HEAD	CT	0.32982	1.13435	0.32982	8.12	0.04079	0.09005	0.04079	20	0.32500	4.18700	0.32500

See NOTES on the last page of this table for Explanation of Column Headings

Notes

1. The resources listed in this table are as of the Date of Study (DOS) and have been calculated using a discount rate (d) of 10 percent. The Date of Study (DOS) is 3 years before the Beneficial Occupancy Date (BOD). All tasks are assumed to occur at mid-year. All resources have been assumed to be constant with no differential escalation from year to year.

2. Component Description - This column contains an indented list of systems, subsystems, components, and high cost task descriptions.

3. Unit of Measure (UM) - This column contains a two-character code to indicate the measurement unit for the component. Units used in this column are as follows:

CT	Count
LF	Linear Foot
SF	Square Foot
TF	Thousands of Linear Feet

4. Labor - Labor resources can be used in one of two ways: (1) labor hours per unit of measure, or (2) dollars per unit of measure assuming a $1.00/hr labor rate.

5. Materials - Material resources are expressed in dollars per unit of measure in July 1988 dollars for the Washington, DC, area.

6. Equipment - Equipment resources can be used in one of two ways: (1) equipment hours per unit of measure, or (2) dollars per unit of measure assuming a $1.00/hr equipment rate.

7. Washington, DC, Total - The dollars per unit of measure figures were calculated by applying the Military District of Washington labor and equipment rates to the labor and equipment resources, then adding the labor, material, and equipment costs together to form one total cost figure.

8. Year (YR) - This column contains the average age of the component when the high-cost task or replacement task would be performed.

9. Engineered Performance Standards (EPS) - Most labor and equipment resource data is based on the DOD series of Technical Bulletins as discussed in the body of the report.

APPENDIX C:

TECHNICAL BULLETIN INDEX FOR ENGINEERED PERFORMANCE STANDARDS

TB No.	Date	Title
TB 420-1	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Engineers Manual (NAVDOCKS P-700.0)
TB 420-2	5 Oct 72	Engineered Performance Standards Public Works Maintenance: General Handbook (NAVDOCKS P-701.0)
TB 420-3	5 Oct 72	Engineered Performance Standards Public Works Maintenance: General Formulas
TB 420-4	1 Mar 82	Tri-Service Coordination of the Carpentry Handbook
TB 420-5	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Carpentry Formulas
TB 420-6	1 Feb 82	Tri-Service Coordination of the Electric, Electronic Handbook
TB 420-7	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Electric, Electronic Formulas
TB 420-8	1 Feb 82	Tri-Service Coordination of the Heating, Cooling and Ventilating Handbook
TB 420-9	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Heating, Cooling, Ventilating Formulas
TB 420-10	1 Apr 81	Engineered Performance Standards Real Property Maintenance Activities Janitorial Handbook
TB 420-11	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Janitorial Formulas
TB 420-12	1 Apr 83	Engineered Performance Standards Real Property Maintenance Activities Machine Shop, Machine Repairs Handbook
TB 420-13	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Machine Shop and Repairs Formulas
TB 420-14	Sep 80	Engineered Performance Standards Real Property Maintenance Activities: Masonry Handbook
TB 420-15	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Masonry Formulas
TB 420-16	1 Apr 81	Engineered Performance Standards Real Property Maintenance Activities: Moving, Rigging Handbook
TB 420-17	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Moving, Rigging Formulas

TB 420-18	1 Nov 78	Engineered Performance Standards Real Property Maintenance Activities: Paint Handbook
TB 420-19	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Paint Formulas
TB 420-20	1 Aug 83	Engineered Performance Standards Real Property Maintenance Activities: Pipefitting, Plumbing Handbook
TB 420-21	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Pipefitting, Plumbing Formulas
TB 420-22	1 Sep 80	Engineered Performance Standards Public Works Maintenance: Roads, Grounds, Pest Control, Refuse Collection Handbook
TB 420-24	1 Mar 84	Engineered Performance Standards Real Property Maintenance Activities: Sheet Metal, Structural Iron and Welding Handbook
TB 420-25	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Sheet Metal, Structural Iron and Welding Handbook
TB 420-26	1 Nov 79	Engineered Performance Standards Real Property Maintenance Activities: Trackage Handbook
TB 420-27	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Trackage Formulas
TB 420-28	1 Nov 79	Engineered Performance Standards Real Property Maintenance Activities: Wharfbuilding Handbook
TB 420-29	5 Oct 72	Engineered Performance Standards Public Works Maintenance: Wharfbuilding Formulas
TB 420-30	1 Aug 79	Engineered Performance Standards Real Property Maintenance Activities: Emergency/Service Handbook
TB 420-31	1 Dec 73	Engineered Performance Standards Real Property Maintenance Activities: Planner and Estimator's Workbook (Instructor's Manual) (S&I OCE)
TB 420-32	1 Mar 80	Engineered Performance Standards Real Property Maintenance Activities: Planner and Estimator's Workbook, Student's Manual
TP 420-33	1 Aug 83	Engineered Performance Standards Real Property Maintenance Activities: Unit Price Standards Handbook
TB 420-34	1 Mar 84	Engineered Performance Standards Real Property Maintenance Activities: Preventive/Recurring Maintenance Handbook
TB 420-35	1 Apr 81	Tri-Service Coordination of the Moving, Rigging Handbook
TB 420-51	30 Oct 73	Engineered Performance Standards Public Works Maintenance: Facilities Engineering Management of Maintenance Painting of Facilities

APPENDIX D:

GEOGRAPHICAL LOCATION ADJUSTMENT FACTORS

State	Location	ACF Index
Alabama	State Average	.86
	Birmingham	.96
	Mobile	.86
	Montgomery	.76
	Anniston Army Depot	.81
	Huntsville	.88
	Fort McClellan	.80
	Redstone Arsenal	.88
	Fort Rucker	.80
Alaska	State Average	2.25
	Anchorage	1.92
	Delta Junction	2.70
	Fairbanks	2.13
	Adak	3.88
	Aleutian Islands	3.86
	Anchorage NSGA	1.92
	Barrow	4.18
	Burnt Mtn.	6.86
	Clear	3.10
	Eielson AFB	2.13
	Elmendorf AFB	1.92
	Galena	3.73
	Fort Greely	2.70
	Fort Richardson	1.92
	Fort Wainwright	2.13
Arizona	State Average	1.02
	Flagstaff	1.02
	Phoenix	.99
	Tucson	1.05
	Fort Huachuca	1.22
	Yuma Proving Ground	1.31
	Yuma	1.31
Arkansas	State Average	.89
	Pinebluff	.93
	Little Rock	.83
	Fort Smith	.92
	Fort Chaffee	.92
	Pine Bluff Arsenal	.93
California	State Average	1.21
	Los Angeles	1.20
	San Diego	1.18
	San Francisco	1.25
	Beale	1.28
	Bridgeport NWTC	1.27
	Castle	1.13
	Centerville Beach	1.32
	Desert Area	1.18
	Edwards AFB	1.30

State	Location	ACF Index
California (Cont'd)	El Centro	1.27
	George AFB	1.31
	Fort Hunter Liggett	1.29
	Fort Irwin	1.20
	Le Moore NAS	1.20
	March AFB	1.18
	Mather AFB	1.17
	McClellan AFB	1.17
	Monterey Area	1.23
	Presidio of Monterey	1.23
	Norton AFB	1.16
	Oakland Army Base	1.33
	Fort Ord	1.24
	Port Huenema Area	1.20
	Riverside	1.18
	Sacramento	1.15
	Sacramento Army Depot	1.15
	Presidio of San Francisco	1.25
	San Nicholas Island	2.59
	Sharpe Army Depot	1.13
	Sierra Army Depot	1.33
	Stockton	1.15
	Travis AFB	1.27
	Vandenburg AFB	1.38
Colorado	State Average	.98
	Colorado Springs	.94
	Denver	1.04
	Pueblo	.96
	Fort Carson	1.01
	Fitzsimmons AMC	1.06
	Pueblo Army Depot	.96
	Peterson AFB	.94
	Rocky Mountain Arsenal	1.06
Connecticut	State Average	1.13
	Bridgeport	1.16
	Hartford	1.10
	New London	1.14
Delaware	State Average	.99
	Dover	1.04
	Lewes	.98
	Milford	.96
	Lewes NF	1.04
	Dover AFB	1.04
District of Columbia	Washington	1.03
	Fort McNair	1.03
	Walter Reed AMC	1.03
Florida	State Average	.89
	Miami	.95
	Panama City	.92
	Tampa	.79
	Cape Canaveral	.96
	Cape Kennedy	.96

State	Location	ACF Index
Florida (Cont'd)	Gulf Coast	.85
	Homestead AFB	.88
	Homestead	.88
	Jacksonville Area	.85
	Key West NAS	1.08
	Orlando	.80
	Pensacola Area	.85
	McDill AFB	.77
	Eglin AFB	.77
	Tyndall AFB	.92
Georgia	State Average	.80
	Albany	.82
	Atlanta	.87
	Macon	.70
	Athens	.90
	Atlanta-Marietta	.93
	Fort Benning	.71
	Columbus	.71
	Fort Gillem	.87
	Fort Gordon	.94
	Kings Bay	.93
	Fort McPherson	.87
	Fort Stewart	.84
Hawaii	State Average	1.28
	Hawaii	1.29
	Honolulu	1.27
	Maui	1.29
	Alimanu	1.27
	Barbars Point NAS	1.34
	Fort Debussy	1.27
	E[illegible] Beach Area	1.34
	He[illegible]manc	1.34
	Hickam Army Air Field	1.27
	Kaneohe MCAS	1.34
	Moanalua	1.27
	Pearl City	1.27
	Pearl Harbor	1.27
	Pohakuloa	1.32
	Schofield Barracks	1.27
	Fort Shafter	1.27
	Tripler AMC	1.27
	Wheeler Army Air Field	1.34
Idaho	State Average	1.11
	Boise	1.05
	Idaho Falls	1.08
	Mountain Home	1.19
	Mountain Home AFB	1.20
Illinois	State Average	1.03
	Belleville	.96
	Chicago	1.09
	Rock Island	1.03
	Rock Island Arsenal	1.06

State	Location	ACF Index
Illinois (Cont'd)	St. Louis Support Ctr	.96
	Savannah Army Depot	1.05
	Scott AFB	1.03
	Fort Sheridan	1.10
Indiana	State Average	.99
	Indianapolis	1.03
	Logansport	.99
	Madison	.94
	Fort Benjamin Harrison	1.07
	Crane	1.10
	Crane AAP	1.10
	Grissom AFB	1.06
	Indiana AAP	1.02
	Jefferson Proving Ground	.94
Iowa	State Average	1.02
	Burlington	1.04
	Cedar Rapids	.98
	Des Moines	1.05
	Iowa AAP	1.06
Kansas	State Average	.94
	Manhattan	.97
	Topeka	.96
	Wichita	.88
	Kansas AAP	.94
	Fort Leavenworth	.94
	Fort Riley	.97
	Sunflower AAP	.97
Kentucky	State Average	.96
	Bowling Green	.99
	Lexington	.96
	Louisville	.93
	Fort Campbell	.93
	Fort Knox	.99
	Lexington/Bluegrass Army Depot	1.06
	Louisville NAS	.93
Louisiana	State Average	.92
	Alexandria	.87
	New Orleans	.94
	Shreveport	.94
	Barksdale AFB	.94
	England AFB	.87
	Gulf Outport New Orleans	.94
	Louisiana AAP	.94
	Fort Polk	.94
Maine	State Average	.93
	Bangor	.85
	Caribou	.99
	Portland	.94
	Brunswick	.93
	Cutler	.98
	Northern Area	1.17
	Winter Harbor	.98

State	Location	ACF Index
Maryland	State Average	.97
	Baltimore	.95
	Fredrick	.94
	Lexington Park	1.01
	Aberdeen Proving Ground	.94
	Annapolis	1.03
	Fort Detrick	.94
	Harry Diamond Lab	1.00
	Fort Meade	.95
	Patuxent River Area	1.08
	Fort Ritchie	.90
Massachusetts	State Average	1.10
	Boston	1.13
	Fitchburg	1.08
	Springfield	1.08
	Army Mtls & Mech Research Ctr	1.13
	Fort Devens	1.15
	Natick Research & Development Ctr	1.13
	South Weymouth	1.13
Michigan	State Average	1.06
	Bay City	1.02
	Detroit	1.14
	Marquette	1.03
	Detroit Arsenal	1.14
	Northern Area	1.25
	Republic (Elfcom)	1.10
	Selfridge AFB	1.14
Minnesota	State Average	1.08
	Duluth	1.05
	Minneapolis	1.09
	St. Cloud	1.10
	Twin Cities AAP	1.09
Mississippi	State Average	.84
	Biloxi	.87
	Columbus	.81
	Jackson	.84
	Columbus AFB	.81
	Gulfport Area	.87
	Meridian	.92
Missouri	State Average	.92
	Kansas City	.92
	St. Louis	.99
	Rolla	.85
	Lake City AAP	.93
	Fort Leonard Wood	.91
Montana	State Average	1.15
	Billings	1.15
	Butte	1.18
	Great Falls	1.12
	Malmstrom AFB	1.12
Nebraska	State Average	1.03
	Grand Island	1.00

State	Location	ACF Index
Nebraska (Cont'd)	Lincoln	1.05
	Omaha	1.05
	Offutt AFB	1.05
Nevada	State Average	1.18
	Hawthorne	1.26
	Las Vegas	1.13
	Reno	1.15
	Fallon	1.28
	Hawthorne AAP	1.26
	Nellis AFB	1.13
New Hampshire	State Average	1.09
	Concord	1.06
	Nashua	1.06
	Portsmouth	1.14
	Cold Regions Lab	1.17
New Jersey	State Average	1.08
	Newark	1.11
	Red Bank	1.08
	Trenton	1.06
	Bayonne	1.10
	Bayonne Mil Ocean Term	1.09
	Fort Dix	1.03
	Earle	1.10
	Lakehurst	1.05
	Fort Monmouth	1.09
	Picatinny Arsenal	1.20
New Mexico	State Average	1.03
	Alamogordo	.99
	Albuquerque	1.03
	Gallup	1.06
	Holloman AFB	1.05
	Kirtland AFB	1.03
	White Sands Missile Range	1.09
	Fort Wingate	1.06
New York	State Average	1.12
	Albany	1.07
	New York City	1.24
	Syracuse	1.05
	Brooklyn	1.24
	Fort Drum	1.18
	Fort Hamilton	1.24
	Seneca Army Depot	1.15
	U.S. Military Academy	1.17
	Watervliet Arsenal	1.07
North Carolina	State Average	.76
	Fayetteville	.76
	Greensboro	.75
	Wilmington	.78
	Fort Bragg	.76
	Camp Lejeune Area	.86
	Cherry Point	.86
	Goldsboro	.77

State	Location	ACF Index
North Carolina (Cont'd)	Pope AFB	.82
	Seymour AFB	.77
	Sunny Point Mil Ocean Term	.78
North Dakota	State Average	1.03
	Bismarck	1.02
	Grand Forks	.98
	Minot	1.10
	Grand Forks AFB	.98
	Stanley R. Hicklesen CPX	1.03
	Minot AFB	1.12
Ohio	State Average	1.00
	Columbus	1.03
	Dayton	.98
	Youngstown	.99
	Cleveland	1.14
	Wright-Patterson AFB	.98
Oklahoma	State Average	.93
	Lawton	.90
	McAlester	.91
	Oklahoma City	.98
	Altus AFB	.94
	Enid	1.01
	McAlester AAP	.91
	Fort Sill	.90
Oregon	State Average	1.05
	Pendleton	1.08
	Portland	1.07
	Salem	.99
	Charleston	1.11
	Coos Head	1.08
	Umatilla Army Depot	1.18
Pennsylvania	State Average	1.00
	Harrisburg	.91
	Philadelphia	1.05
	Pittsburgh	1.04
	Carlisle Barracks	.93
	New Cumberland Army Depot	.91
	Fort Indiantown Gap	1.07
	Letterkenny Army Depot	1.07
	Mechanicsburg Area	.91
	Tobyhanna Army Depot	1.14
	Warminster Area	1.04
Rhode Island	State Average	1.11
	Bristol	1.13
	Newport	1.11
	Providence	1.10
	Davisville	1.17
South Carolina	State Average	.82
	Charleston	.81
	Columbia	.82
	Myrtle Beach	.84
	Beaufort Area	.89

State	Location	ACF Index
Virginia (Cont'd)	Arlington Hall Station	1.04
	Arlington National Cemetery	1.04
	Fort Belvoir	1.04
	Cameron Station	1.04
	Dahlgren	1.10
	Fort Eustis	.96
	Humphreys Engineer Center	1.03
	Fort A. P. Hill	.92
	Fort Lee	.93
	Fort Monroe	.94
	Fort Myer	1.03
	Norfolk-Newport News Area	.95
	Fort Pickett	.98
	Quantico	1.03
	Nadford AAP	1.02
	Port Story	.95
	Vint Hill Farms Station	1.08
Washington	State Average	1.09
	Spokane	1.08
	Tacoma	1.07
	Yakima	1.11
	Fairchild AFB	1.13
	Jim Creek	1.34
	Fort Lewis	1.07
	Pacific Beach	1.27
	Puget Sound Area	1.15
	Seattle Area	1.12
	Widbey Island	1.12
	Yakima Firing Center	1.18
West Virginia	State Average	.95
	Bluefield	.92
	Clarksburg	.95
	Charleston	.99
	Sugar Grove	1.15
Wisconsin	State Average	1.06
	LaCrosse	1.04
	Madison	1.02
	Milwaukee	1.13
	Badger AAP	1.06
	Clam Lake	1.20
	Fort McCoy	1.11
Wyoming	State Average	1.08
	Casper	1.07
	Cheyenne	1.10
	Laramie	1.08
	F. E. Warren AFB	1.10

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